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The Effect of Beaver (Castor canadensis) Dams on the Vegetation of Tidal Marshes

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THE EFFECT OF BEAVER (*CASTOR CANADENSIS*) DAMS ON THE VEGETATION OF TIDAL MARSHES

A THESIS

Presented to

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Master of Arts

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by

Mary H. Causey

1984

APPROVAL SHEET

This thesis is submitted in partial fulfillment of

the requirements for the degree of

Master of Arts

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ABSTRACT

Beaver (Castor canadensis) populations have expanded into Virginia tidal marshes since their reintroduction in the state. The effect that beaver dams have on Virginia's wetland jurisdiction and the change in vegetation found at the dams was investigated. The dams do not alter the jurisdiction of Virginia under the Virginia Wetlands Act, although the dam itself appears to be included in the protection provided wetlands by the Virginia Wetlands Act. The observed vegetation changes coinciding with one dam in a tidal freshwater marsh (Unicorn Creek) and two dams on a brackish marsh (Ware Creek) on the Pamunkey and York Rivers, Virginia, were studied utilizing net production, diversity and species composition. Net production decreased significantly at the 1% level on both brackish and freshwater impounded marshes. Diversity, as measured by the Shannon Weaver diversity index, decreased significantly at the 1% level in the freshwater marsh. In the brackish water marsh the decrease was significant at the 1% level when the vegetation on the second dam was considered the result of beaver activity, rather than the presence of the first dam. Species composition changed in both fresh and brackish water marshes. There is a dearth of conclusive evidence that the dam is the cause of this vegetation change, however, the change in vegetation coinciding with the dam, the data collected from 1939 aerial photographs and comparisons with 1979 inventories of the area empirically lead one to conclude that the dam does cause the decrease in diversity, net production and the change in species composition found at the beaver dam.

THE EFFECT OF BEAVER (*CASTOR CANADENSIS*)
DAMS ON THE VEGETATION OF TIDAL MARSHES

INTRODUCTION

The Virginia population of beavers (*Castor canadensis*) has gone from near extinction in the 1930's to a thriving, growing population in the 1980's. In these last 50 years beavers have moved into the marshes of the Mattaponi and Pamunkey Rivers, Virginia (Chief Cook, chief of the Pamunkey Indians, pers. comm.). Using aerial observation and photographs, fourteen beaver dams have been sighted in tidal marshes in Virginia, nine on the York River system and five on the Potomac River system. The effect of beavers and their dams on tidal marshes is unknown and in order to address this lack of information, a study was designed to: 1. study the vegetation above and below a beaver dam in a tidal freshwater marsh and a tidal brackish marsh, 2. investigate the evidence indicating the dam as the cause of the apparent difference in vegetation, and 3. assess the impact beaver dams may have on wetland jurisdiction in Virginia.

A beaver dam in a tidal marsh can be detected from the air and on the ground by the visible, abrupt change in vegetation found at the dam. Low level flights were made over the tidal portions of the Mattaponi and Pamunkey Rivers and the upper portion of the York River, Virginia, in September of 1980 and in May of 1984 to obtain a census of the dams in these areas (Map I). Nine dams were observed on tributary creeks of these three rivers: five associated with the Mattaponi, two with the

Pamunkey and two with the York River on Ware Creek (Map II). Species composition, productivity, and diversity of the vegetation were used to compare the vegetation above and below the dams in brackish and freshwater marshes impounded by beaver dams.

Literature Search

Beaver impoundments

The effects of beaver dam construction in tidal wetlands and the resultant impoundment apparently have not been approached as a research subject. A recent review of the literature concerning beavers (Hodgdon and Larson, 1980) points out the wide range of research done concerning *C. canadensis*, but no studies of beaver in tidal marshes are mentioned. A DIALOG computerized literature search for studies on the combination of beaver dams and marshes yielded no references to the presence of beavers in tidal marshes nor were references found concerning the effect of beaver dams on their environment in tidal marshes. Beaver were found in the tidal freshwater marshes on the Chickahominey River, Virginia. Wild rice was observed on both sides of the dams, with the only difference being that the wild rice was more open upstream of the dam (Odum et al. 1984). Other references pertaining to the animals associated with tidal marshes do not recognize beavers as a tidal marsh inhabitant (Daiber, 1982).

Beavers have been reported in the literature as a mammal that exists in wetland habitats (Weller, 1981; Shaw and Fredine, 1956; Chabreck, 1978) and as a mammal that creates marsh by changing streams to productive wetlands (Naiman et al. 1984; Weller, 1981). Herbaceous wetlands are considered a beaver habitat in a habitat suitability model

(Allen, 1982). Even though Allen discussed beaver use of wetlands, tidal wetlands are not specifically addressed. Palustrine and lacustrine wetlands, both non-tidal systems, are the only ones considered in Allen's study. The United States Fish and Wildlife Service (Shaw and Fredine, 1956) studied the wetlands of the United States in relation to their value to wildlife. Beavers were reported using fresh and saline inland wetlands and coastal wetlands, but beaver use of coastal wetlands was reported by only a few states. Virginia's study of wildlife use of wetlands reported no use of coastal wetlands by beavers (Office of River Basin Studies, 1954). In Weller's 1981 study of the wildlife found in tidal and inland marshes, the beaver is recognized as a marsh inhabitant, but tidal marshes are not specifically described as a habitat for beavers. Weller (1981) found no documentation of beaver success when they move into the marsh environment. A study of Maryland's coastal wetland vegetation, including its value to wildlife, recognizes beavers as utilizing wetland plants for food (McCormick and Somes, 1982).

Beaver dams are found in the non-tidal wetlands of Beaverdam Creek, a tributary of the Ware River, Gloucester County, Virginia (Aitkenhead and Jones, 1983). The beaver dams are responsible for creating open water and herbaceous wetlands behind the dams, increasing the floral diversity and providing a variety of wetland habitats (Aitkenhead and Jones, 1983).

Studies have been done on the effect of beaver dams on their environment in non-tidal areas. A comparison of the vegetation surrounding active beaver dams and abandoned dams was reported by Neff (1957) in Colorado. Production indices of grasses and sedges are higher in the abandoned areas than in the active areas. The poor production recorded on the occupied sites is attributed to the large inundated area behind the dam (Neff, 1957). Naiman and Melillo have done studies on the effect of beaver dams on various components of the environment (Naiman and Melillo, 1984; Naiman et al. 1984). Dam building and feeding habits of beavers alter the stream ecosystem. Dams retain sediment, organic matter and water resulting in a changed channel geomorphology and modified nutrient cycles (Francis et al. 1983; Naiman et al. 1984). Habitat diversity is increased by the creation of small "disturbance zones" (Naiman and Melillo, 1984). Aquatic productivity is increased by leaching of nitrogen and phosphorus from the flooded area (Naiman and Melillo, 1984) while total productivity is increased by enlarging the shoreline and water surface area (Naiman et al. 1984). Naiman and Melillo (1984) note there are few instances of quantification of the changes in an ecosystem because of beaver dams.

Man-made impoundments

The impact of the manipulation of the water level in impoundments on the vegetation which attracts waterfowl has been investigated (Harris and Marshall, 1963; Fredrickson, 1982). Water is removed and reflooded at varying rates, at different times of the year. Manipulating water levels in seasonally flooded impoundments produces different types of vegetation (Fredrickson, 1982). Annual drawdowns, draining the impoundment, early in the growing season result in higher total seed production, whereas drawdowns later in the season produce higher stem density and greater species diversity. The rate at which water is removed also affects the vegetative cover. Higher diversity is recorded when early season drainage is done slowly, over a period of two weeks or more. A more uniform vegetation community appears after a quicker (within a few days) early season drawdown, whereas the quicker drainage late in the growing season results in plants less valuable to waterfowl.

Vegetation changes resulting from long term drawdown (one or more years of water level reduction) and subsequent restoration of water levels were monitored in the Agassiz National Wildlife Refuge, Minnesota. The species flooded, the depth of the flood water, and the length of time the area is flooded determine the vegetation of impounded areas. Annuals are eliminated in the first year. A four year period of inundation with 38.1cm of water kills everything except a cattail hybrid (Harris and Marshall, 1963).

The impact of an impoundment on vegetation in a non-tidal area is predicted by an Environmental Impact Statement (EIS) for a proposed reservoir impoundment in Gloucester, Virginia (Aitkenhead and Jones, 1983). According to the EIS there will likely be at least five effects: 1. species endemic to the flooded area will colonize newly impounded areas, thus an emergent wetland will remain that way; 2. the impoundment will kill the hardwoods; 3. new wetlands will establish themselves naturally within 4 feet of the pool level; 4. those wetlands within this 4 foot range of pool level will remain viable wetlands but the community composition will change; 5. wetlands located more than 10 feet below pool level will be converted to monotypic open water (Aitkenhead and Jones, 1983).

The effect of the impoundment of tidal areas on vegetation has been sparsely studied. Tidewater barriers were erected in Rockefeller Refuge, Louisiana, creating permanently flooded brackish impoundments, permanently flooded freshwater impoundments, and manipulated freshwater impoundments. The vegetation communities of the impounded areas were compared to similar control areas in the refuge. The impounded areas have a lower percentage of vegetative coverage than do the unimpounded control areas. Permanently flooded impoundments have a slightly higher percent coverage than do freshwater manipulated impoundments. The impoundments support a larger number of species than do the control areas, with the manipulated freshwater impoundments having the highest number of species (Chabreck, 1960).

History of beavers

The beaver population has fluctuated over the course of the history of this continent, with much of this fluctuation due to man. When beaver hats were a fashionable necessity, the beaver was trapped from a plentiful population to satisfy this trade. Trapping depleted beaver population throughout the North American continent, and in 1910 the beaver was considered extinct in Virginia. This condition prevailed until 1932 when the Virginia Commission of Game and Inland Fisheries (VCGIF) imported five pairs of beaver. This effort to reintroduce the beaver to Virginia was joined by the National Park Service, and seven more pairs were added in 1937 (Bailey, 1946). This program was continued in many counties throughout the state, effectively reintroducing the beaver to one of its natural habitats.

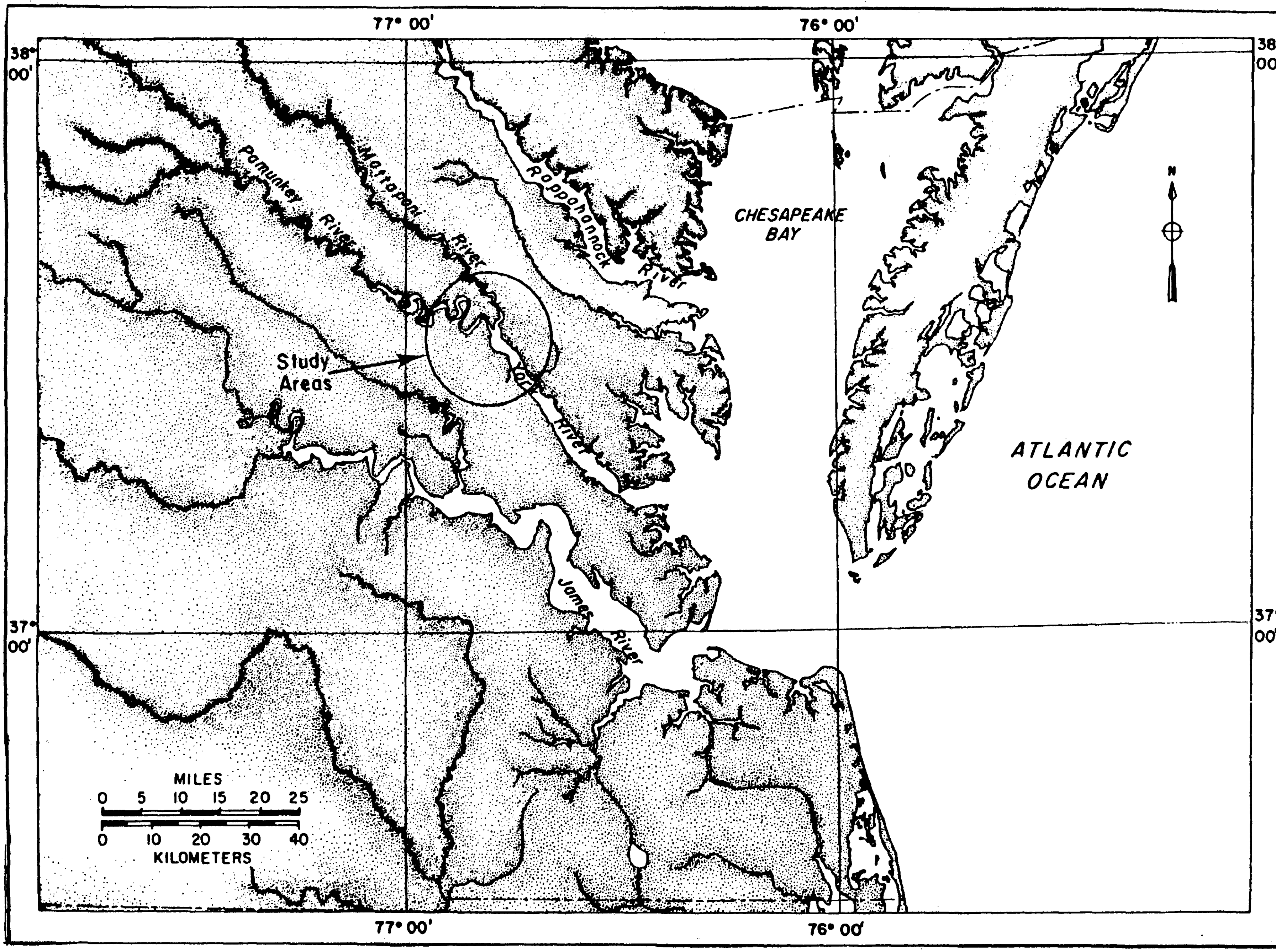
Protection was provided by the Commonwealth for beaver, _Castor canadensis_, by a controlled trapping program. Beavers may not be hunted or shot at any time of the year (VCGIF Reg 4-1:01). In the tidewater area beaver may be trapped by licensed trappers only from December 15 through February 29 (Va. Code 29-139.1).

Since its reintroduction, the beaver population has expanded in Virginia. No organized census is conducted, though some indication of the size of the population can be seen in the number of tagged beavers that the VCGIF reports each year. Because the number of pelts taken is also influenced by the price that the pelts are bringing each year, these numbers can only be seen as an indication of a trend. The number of tagged beavers has risen from approximately 300 in the 1969-1970 season to approximately 13,000 in the 1981-1982 season. Since that year, there has been a decrease in beavers tagged. The 1983-84 statewide total of tagged beavers was 4,821 (VCGIF, 1977, 1983, 1984). The highest number of reported tagged beavers in King William County occurred in 1977-78, and declined from that year. Otherwise, the tagged beaver totals for the counties in the area of the study sites, King William, King and Queen, James City, and New Kent, follow the same pattern as the statewide totals.

The lack of investigation of beavers and the effect of their dams on the environment has been noted and: "...the role of beaver in influencing interactions between terrestrial and aquatic ecosystems, and in the structuring of those ecosystems, deserves serious consideration." (Naiman and Melillo, 1984 p.14). As beaver populations grow and beavers migrate into tidal wetlands, there is increased need for the study of the impact beavers have on the wetland environment.

Map I

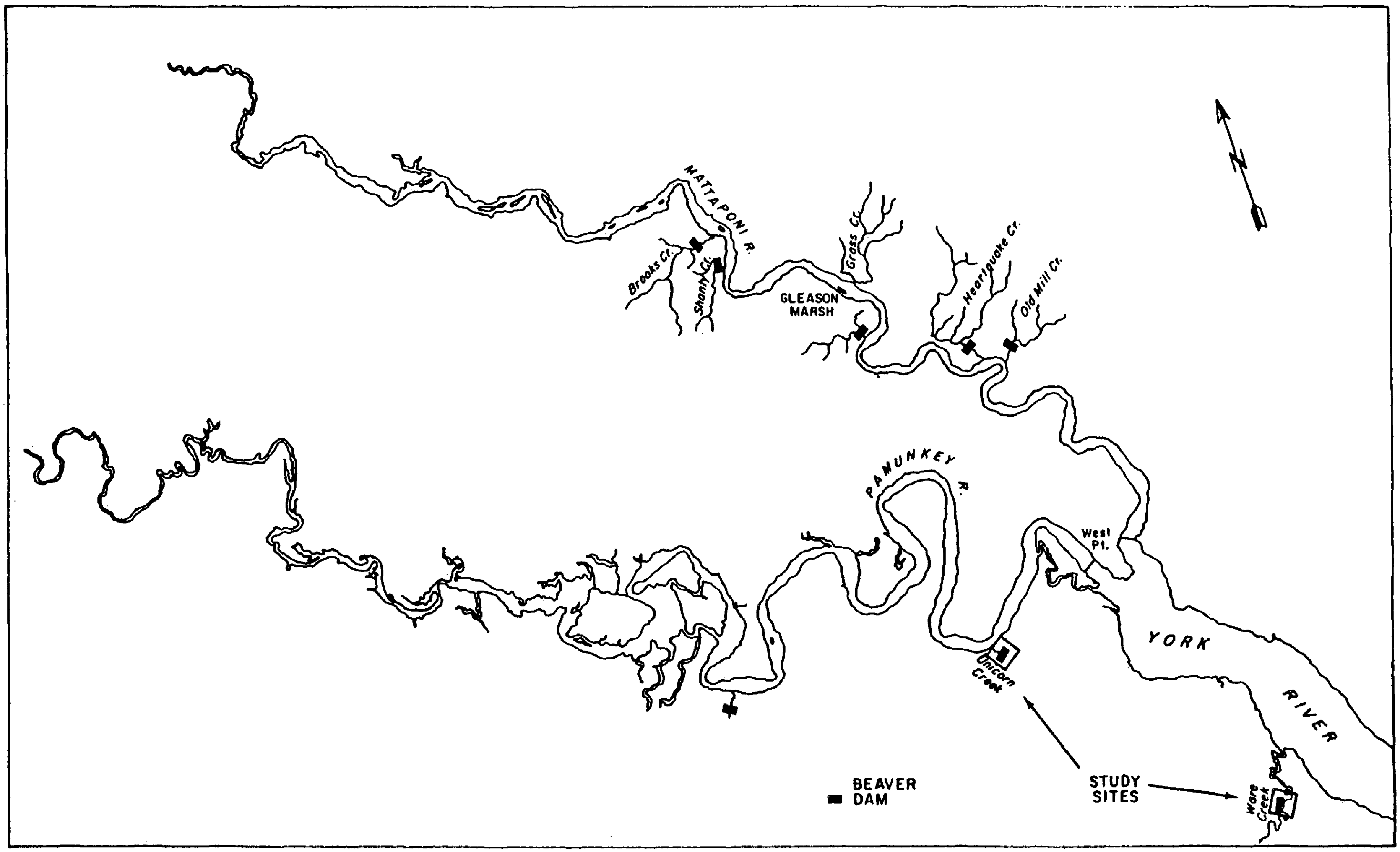
Study Area


77° 00'
76° 00'
38° 00'
37° 00'
Pamunkey River
Mattaponi River
Rappahannock River
York River
James River
Study Areas
CHESAPEAKE BAY
ATLANTIC OCEAN
N
MILES
0 5 10 15 20 25
0 10 20 30 40
KILOMETERS

Map II

Mattaponi, Pamunkey, and York Rivers

with Sighted Beaver Dams Indicated


MATTAPONI R.
Brooks Cr.
Shanty Cr.
GLEASON MARSH
Grass Cr.
Heartquake Cr.
Old Mill Cr.
PAMUNKEY R.
West Pt.
YORK RIVER
Unicorn Creek
Ware Creek
STUDY SITES
BEAVER DAM
N

METHODS

Site Study

Two accessible creeks, each containing at least one beaver dam, identified through the use of aerial photographs taken from an altitude of 900 to 1,200 meters, were chosen as study sites (Map II). Each marsh was ground truthed confirming its tidal nature and the presence of a dam. A sampling scheme was set up to document the apparent change in vegetation observed above beaver dams in a brackish marsh on Ware Creek and in a freshwater marsh on Unicorn Creek. Historical data were investigated to assess evidence supporting the hypothesis that the beaver dams were the cause of observed changes in vegetation.

Contained within a mixed pine-hardwood forest located on a rolling coastal plain, Ware Creek is a tributary of the York River (Map III). It is encompassed by 196 hectares of marsh ranging from brackish marsh at its mouth to freshwater marsh at its upper reaches (Doumlele, 1979; Moore, 1980). Ware Creek is itself fed by several smaller tributaries. The study site containing the two beaver dams is located on one of these tributary creeks in a brackish marsh (Map III). A big cordgrass (Spartina cynosuroides) marsh extends up to the dam. The big cordgrass community ends abruptly on a line coinciding with the vegetation growing on the first beaver dam and is replaced by an arrow arum community. The dam itself is approximately 3 m high, 2 m wide and 213 m in length and is constructed of various lengths and widths of tree trunks and branches making a structure solid enough to walk across with relative ease. The impounded area includes mainly open water with scattered populations of arrow arum (*Peltandra virginica*). The former creek channel can be traced on the aerial photographs and observed in the field. The arrow arum community is interrupted by a line of vegetation growing on the second dam composed predominately of marsh mallow (*Hibiscus moscheutos*) and swamp milkweed (*Asclepias incarnata*). The second dam is approximately 239 m long and 2 meters wide. The impounded area above the second dam is also an arrow arum community in open water with a visible creek channel.

The second site chosen was an unnamed tidal marsh creek, hereafter referred to as Unicorn Creek. Unicorn Creek and an unnamed tidal creek of similar physical features and plant communities join the Pamunkey River approximately 8.3 km upriver from West Point, Virginia (Map IV). The unnamed creek is surrounded by 14 hectares of big cordgrass marsh (Doumlele, 1979) and contains no beaver dams. Unicorn Creek is surrounded by 16 hectares of big cordgrass community (Doumlele, 1979). This study found that on Unicorn Creek the big cordgrass is replaced approximately 250 meters downstream from the beaver dam by a mixture of vegetation including cattail (*Typha* spp.), saltmarsh cordgrass (*Spartina alterniflora*), arrow arum (*Peltandra virginica*), and marsh mallow (*Hibiscus moscheutos*). The beaver dam itself, covered by a taller line of vegetation dominated by water willow (*Decodon verticillatus*) and water dock (*Rumex verticillatus*), divides the impounded area from the downstream marsh. The dam on Unicorn Creek is of similar construction, height, and width as the dams found on Ware Creek and is approximately 240 m long. The impounded area on Unicorn Creek is vegetated by an arrow arum community mixed with dead trees. The former creek channel winds from the dam upstream to the fastland. Unicorn Creek, like Ware Creek, is located in a mixed pine-hardwood forest on a rolling coastal plain. A beaver lodge constructed of the same type of material as the dam is located just above the dam on Unicorn Creek.

Comparison of vegetation maps, species composition, diversity, and net production of the vegetation above and below the dam was proposed to document the observed change in vegetation above the beaver dam. Vegetation maps of the two sites were prepared through the use of aerial photographs and ground truthing. Two $1m^2$ markers were placed 100 meters apart to establish a scale for the aerial photographs. Color infrared photographs were taken from the bay of a DeHavilland Beaver aircraft in late summer and early fall of 1980. Vegetation maps were drawn from these photographs using a Bausch and Lomb zoom transfer scope model ZT4-H. Communities were delineated based on the differences in color and texture seen on the photographs (Cowardin and Myers, 1974; Shima and Carter, 1976). Each site was ground truthed and the communities confirmed. The area covered by each vegetation community was measured using a Numonics model 1224 electronic digitizer.

Tidal influence and salinity were observed at the two sites. Each dam was visited at an exceptionally high tide and at a low tide to observe the extent of the tidal influence. Salinity samples were taken below the impoundments to confirm the salinities of the two creeks.

Diversity and Productivity Studies

Procedures were established to sample the diversity and productivity of the vegetation on both sides of the dams and the vegetation on each dam. Using the vegetation maps with a grid and a random numbers table, sample sites were selected in each community. One diversity sampling site was established in each dam community because of its small size. Three sites were established in all other communities (Table I). For the productivity studies, the number of sites varied from one in the dam community which was under $100m^2$ to five sites in those communities over $5000m^2$. A sample bag from each arrow arum above-the-dam community was lost in transit from the field, leaving only four sites recorded for these two large communities (Table I).

Diversity

Sites were marked with polyvinyl chloride (PVC) pipe at opposite corners of a meter square quadrat. An early summer (late May or early June) and a late summer (late August or early September) sampling scheme was proposed. All species found within the quadrat at each station were recorded. Using the Braun-Blanquet cover-abundance scale (Wilkum and Shanholtzer, 1978) a number was assigned for each species contained within the quadrat and for the total vegetation within the quadrat.

Productivity

Sampling was done once in September, 1981. The vegetation in $0.25m^2$ plots was clipped at ground level. All the clippings and dead vegetation were collected. It was difficult to determine ground level and collect all live and dead material when the sample plot was inundated because the water was turbid. Dead and live material was separated and sorted according to species. Regional manuals were used for identification purposes (Beal, 1977; Radford et al. 1968; Silberhorn, 1976). Living material, by species, and dead material were placed in paper bags and dried in an oven at 115 degrees centigrade. This higher temperature was used to dry the high water content species to avoid fungus growth. The time required to dry the plants varied from species to species. The dry weight was measured to the nearest 0.01 gram and recorded.

Analysis of Data

A diversity index was calculated using the Shannon Weaver (1949) formula. The Braun-Blanquet numbers had to be converted to a stem count in order to utilize the Shannon Weaver formula which requires a stem count to calculate importance probabilities (Wikum and Shanholtzer, 1978). The Braun-Blanquet numbers were converted to an equivalent of stem count using the following formula:

$$SC = MCR \times TC\%$$

Where:

SC = Stem Count equivalent

MCR= Mid point of Cover Range (Wikum and Shanholtzer, 1978)

TC%= % of meter square Covered by Total vegetation,

The Shannon Weaver diversity index calculations were performed on a Hewlett Packard programmable calculator (Thomas Fredette pers. comm.) using the following formula:

$$H' = -\sum P_i \log P_i$$

where:

Pi = importance probabilities

H' = Shannon Weaver Diversity Index (Shannon and Weaver, 1949)

The Shannon Weaver Index was computed for each quadrat. The Shannon Weaver Diversity Indices for all quadrats in each community were averaged to establish a diversity index for each community.

The data were tested for normal distribution using the Rankit test (Rohlf and Sokal, 1981; Sokal and Rohlf, 1969) and found not to be normally distributed. Therefore, the nonparametric Mann Whitney U test was used to test for the significant difference in the productivity and diversity above and below the dam. The Mann Whitney formula calculates the statistic U as follows:

$$U = Na \times Nb + \frac{Na \quad (Na+1)}{2} - Ra$$

and

$$U = Na \times Nb + \frac{Nb \quad (Nb+1)}{2} - Rb$$

where:

Na = number "above-the-dam" stations

Nb = number "below-the-dam" stations

Ra = total ranks of "above-the-dam"

Rb = total ranks of "below-the-dam"

Both U calculations were done and the smallest U value was used in the tables to determine whether the two groups were drawn from the same population (Siegel, 1956). The diversity indices and productivity data were ranked in order of increasing size (See appendix). The total of ranks for each side of the dam was calculated by adding the ranks of above-the-dam observations and below-the-dam observations.

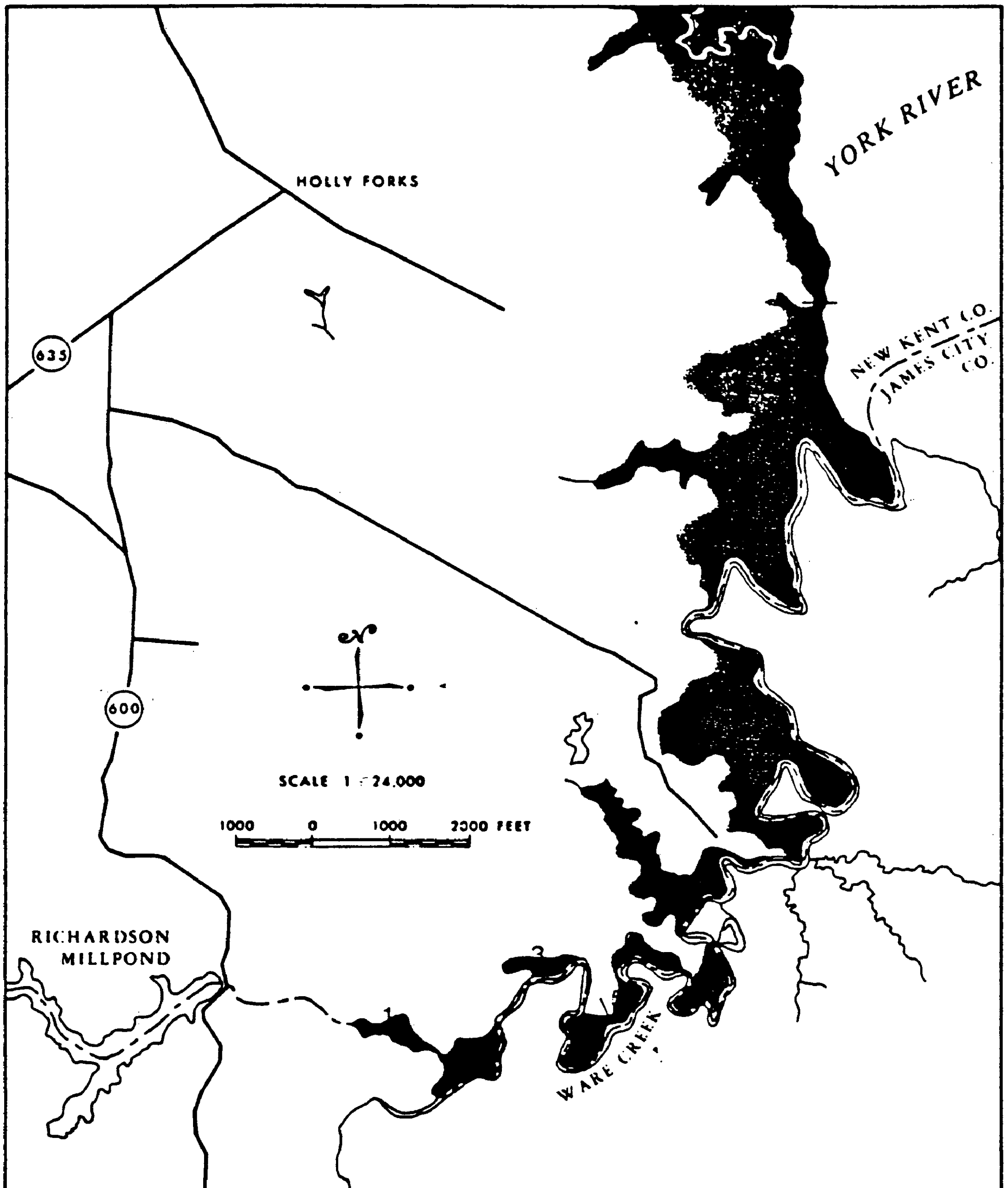
Historical Data

Early photographs of the area which predated the construction of the dams were sought to compare with current photographs to determine if the vegetation changed after the dams were built. The data gathered in this study were also compared to the information found in the Wetland Inventories (Doumlele, 1979).

Map III

Ware Creek

Shaded Areas = Marsh (New Kent County)



WARE CREEK TO HILL MARSH

(Doumlele, 1979, p. 21)

Map IV

Unicorn Creek and Adjacent Creek

Shaded Areas = Marsh (New Kent County)

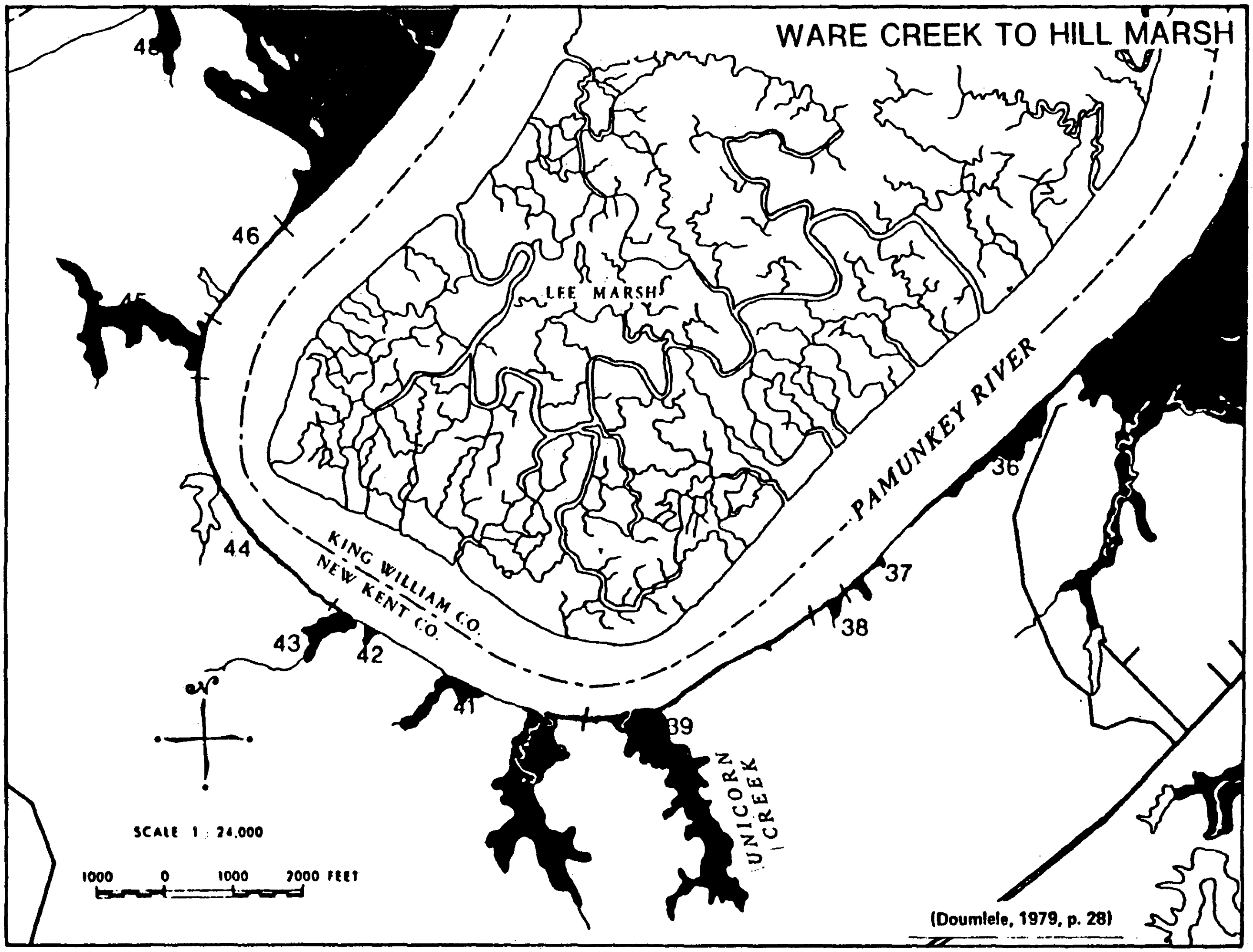

WARE CREEK TO HILL MARSH
LEE MARSH
PAMUNKEY RIVER
KING WILLIAM CO.
NEW KENT CO.
UNICORN CREEK
46
44
43
42
41
39
38
37
36
SCALE 1 : 24,000
1000 0 1000 2000 FEET
(Doumlele, 1979, p. 28)

Table I

Vegetation Communities

Community	Dominant species	Location	sites per community div	prod
Unicorn Creek				
Cordgrass(BCG)	Spartina cynosuroides	below	3	5
Cattail	Typha augustifolia	below	3	4
Saltmarsh cordgrass	Spartina alterniflora	below	3	3
Arrow arum (A-b)	Peltandra virginica	below	3	3
Wax myrtle	Leersia oryzoides	below	3	3
Dam	Hibiscus moscheutos	on/below	1	1
Arrow arum (A-a)	Peltandra virginica	above	3	4
Ware Creek				
Big Cordgrass (BCG)	Spartina cynosuroides	below	3	5
Dam #1	Spartina cynosuroides	on	1	1
Arrow arum (A-be)	Peltandra virginica	between (above)	3	5
Cattail	Typha augustifolia	between (above)	3	3
Dam #2	Peltandra virginica	on(above)	1	1
Arrow arum (A-a)	Peltandra virginica	above	3	4

*First location is physical location in reference to dam. The second location is the one used for statistical analysis, if different from physical location.

RESULTS

Site Study

Both Unicorn and Ware Creeks are under tidal influence as far as the dam, but the tidal waters apparently do not breach either dam even under exceptionally high tide conditions. Though it is possible that a large storm event on a high tide could force the water over the dam, no documentation of this is available.

Ware Creek is an oligohaline creek with a salinity of 4.404 ppt directly below the dam. Unicorn Creek is a freshwater creek. The salinity below the dam measures 0.271 ppt.

Vegetation maps of the two sites are shown in Maps V and VI with the area of each community indicated in m^2. Community classification was based on the apparent dominant species. When two communities have the same dominant species but are located differently with respect to the dam, the location is added to the community designation (e.g., Arrow arum above). Communities, dominant species and their location are seen in Table I. On closer examination of aerial photographs, another dam was found on Ware Creek. This dam, which may have been built between the reconnaissance flight and the flight to photograph the dams, was included in the study. The downstream dam was designated dam #1, and the upstream dam was designated dam #2.

Diversity Studies

Sampling for diversity on Unicorn Creek proceeded according to schedule with sampling done in late May/early June and late September/early October of 1981. For Ware Creek, the September/October sample was completed, but complications prevented sampling in May/June. A species composition list for each creek is found in the appendix. The number of stations which contained each species is indicated, and the location of that station, above-the-dam, on-the-dam, or below-the-dam is given. The diversity data are presented in Table II and Figures I and II.

Production (Biomass) Studies

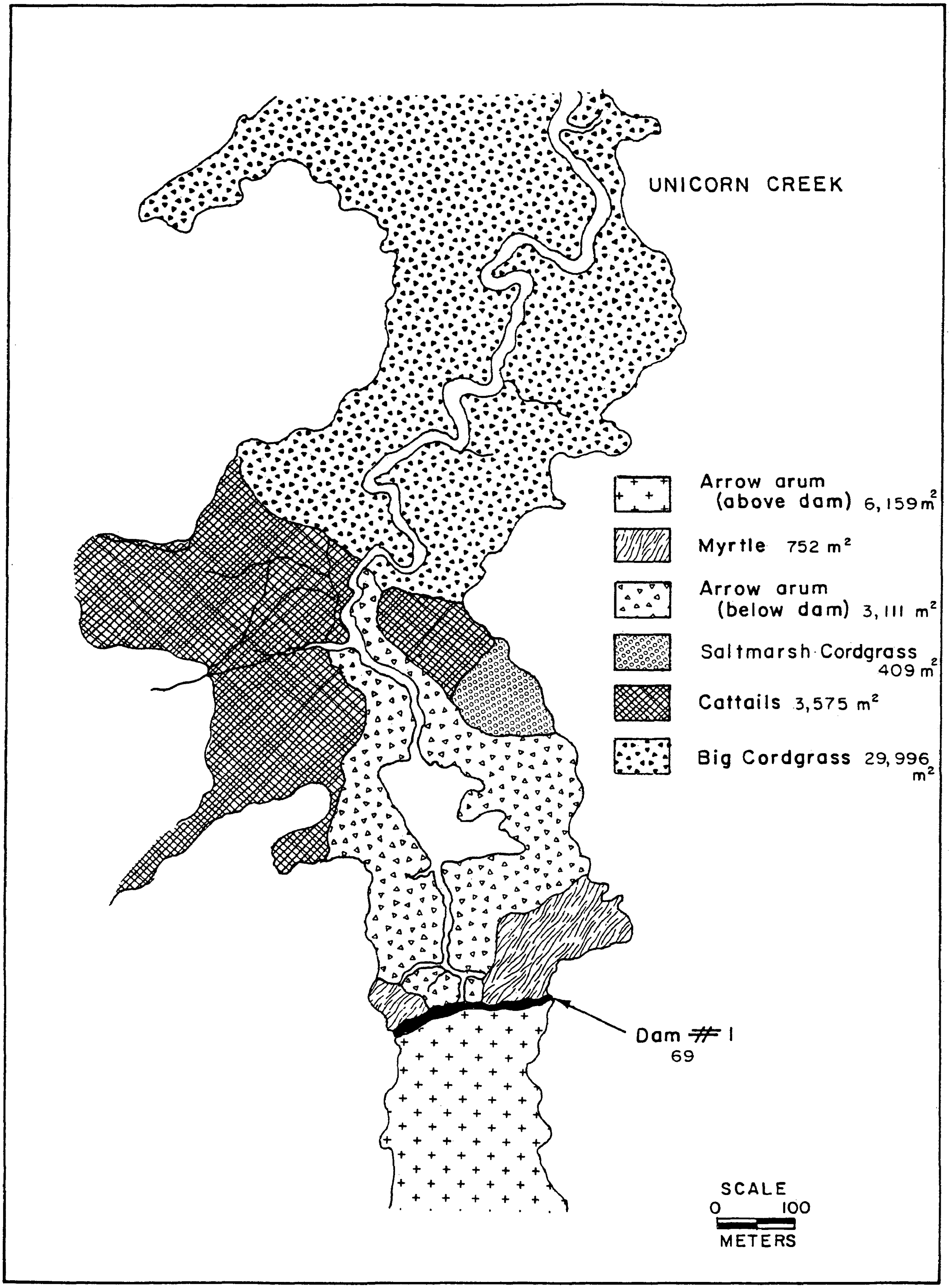
Organic production data were calculated in $gr/m^2/yr$. The total production was determined for each station by adding the measured productivity of all live and dead material. The production of all stations in each community was averaged to calculate the productivity for each community. The results are shown in Table III and Figures III and IV.

Analysis of Data

The data for diversity and productivity were not normally distributed. Tests conducted for normal distribution are found in the appendix. Lacking normal distribution, a basic assumption for parametric statistics, nonparametric statistical analysis was required. The Mann-Whitney U test was chosen as it is " ...one of the most powerful of the nonparametric tests, and it is a most useful alternative to the parametric t test when the researcher wishes to avoid the t test's assumptions..." (Siegel,1956 p. 116). Results of the Mann Whitney U test are shown in Table IV.

Map V

Vegetation Map for Unicorn Creek


UNICORN CREEK
Arrow arum (above dam) 6,159 m²
Myrtle 752 m²
Arrow arum (below dam) 3,111 m²
Saltmarsh Cordgrass 409 m²
Cattails 3,575 m²
Big Cordgrass 29,996 m²
Dam #1
69
SCALE
0 100
METERS

Map VI

Vegetation Map for Ware Creek

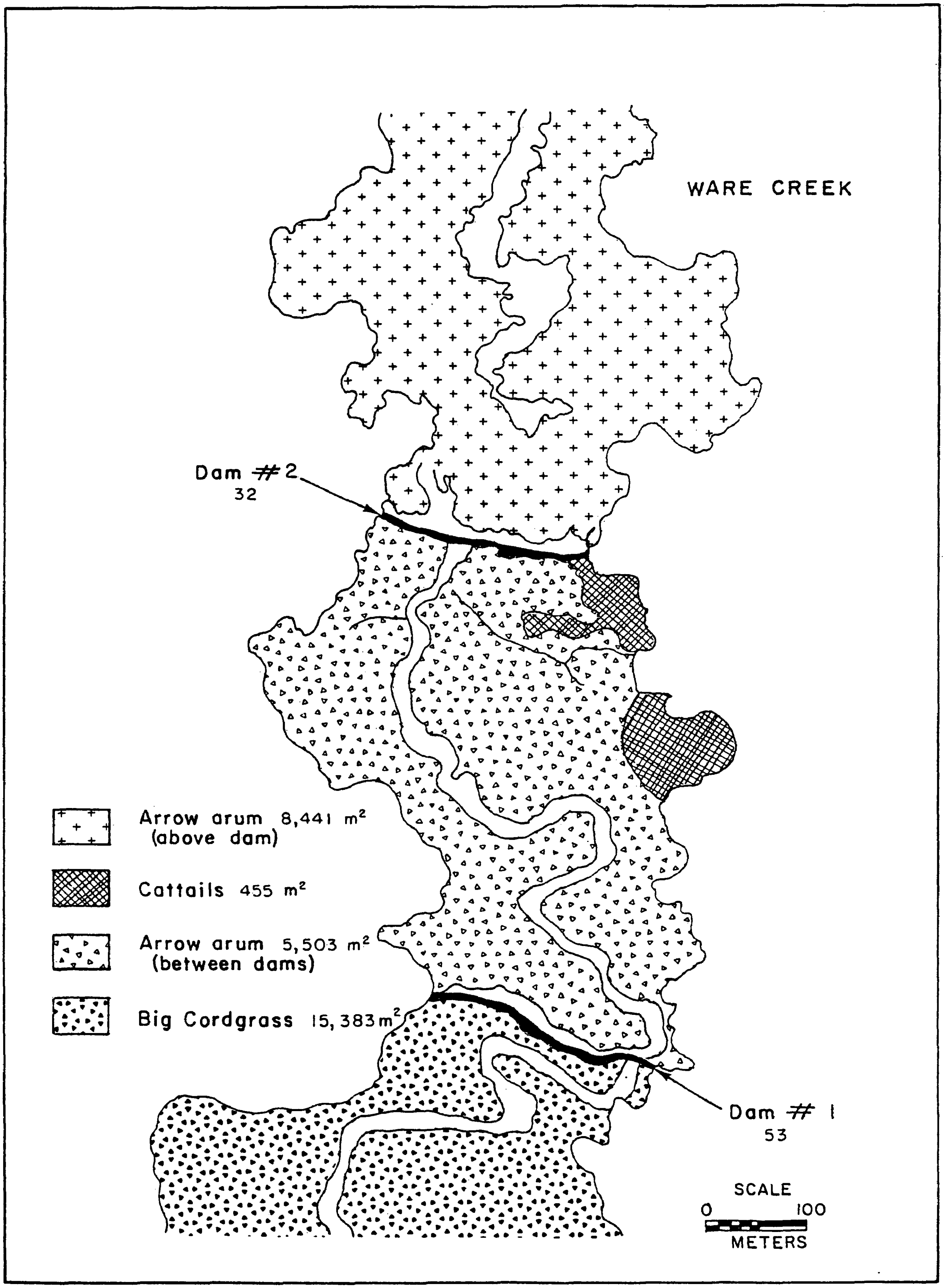

WARE CREEK
Dam #2
32
Dam # 1
53
Arrow arum 8,441 m^2
(above dam)
Cattails 455 m^2
Arrow arum 5,503 m^2
(between dams)
Big Cordgrass 15,383 m^2
SCALE
0 100
METERS

Table II

Shannon Weaver Diversity Index of Fall Sample,

Reported by Stations

Creek	Community	Station	H′
Unicorn	Big cordgrass	1	0.00
Unicorn	Big cordgrass	2	lost
Unicorn	Big cordgrass	3	0.00
Unicorn	Big cordgrass	average	0.00
Unicorn	Cattail	1	0.01
Unicorn	Cattail	2	1.53
Unicorn	Cattail	3	1.86
Unicorn	Cattail	average	1.13
Unicorn	Saltmarsh cordgrass	1	1.41
Unicorn	Saltmarsh cordgrass	2	0.62
Unicorn	Saltmarsh cordgrass	3	2.28
Unicorn	Saltmarsh cordgrass	average	1.44
Unicorn	Arrow arum(below)	1	0.61
Unicorn	Arrow arum(below)	2	1.76
Unicorn	Arrow arum(below)	3	2.03
Unicorn	Arrow arum(below)	average	1.47
Unicorn	Wax myrtle	1	1.42
Unicorn	Wax myrtle	2	1.09
Unicorn	Wax myrtle	3	2.20
Unicorn	Wax myrtle	average	1.57
Unicorn	Dam	1	1.33
Unicorn	Arrow arum(above)	1	0.00
Unicorn	Arrow arum(above)	2	0.00
Unicorn	Arrow arum(above)	3	0.00
Unicorn	Arrow arum(above)	average	0.00

Ware	Big cordgrass	1	1.21
Ware	Big cordgrass	2	1.63
Ware	Big cordgrass	3	1.96
Ware	Big cordgrass	average	1.60
Ware	Dam	1	1.24
Ware	Arrow arum(between)	1	0.00
Ware	Arrow arum(between)	2	0.95
Ware	Arrow arum(between)	3	0.00
Ware	Arrow arum(between)	average	0.32
Ware	Cattail	1	0.01
Ware	Cattail	2	1.39
Ware	Cattail	3	1.08
Ware	Cattail	average	0.83
Ware	Dam	2	1.65
Ware	Arrow arum(above)	1	0.00
Ware	Arrow arum(above)	2	0.00
Ware	Arrow arum(above)	3	0.00
Ware	Arrow arum(above)	average	0.00

Figure I

Shannon Weaver Diversity Index of Fall Samples

from Unicorn Creek,

Reported by Communities

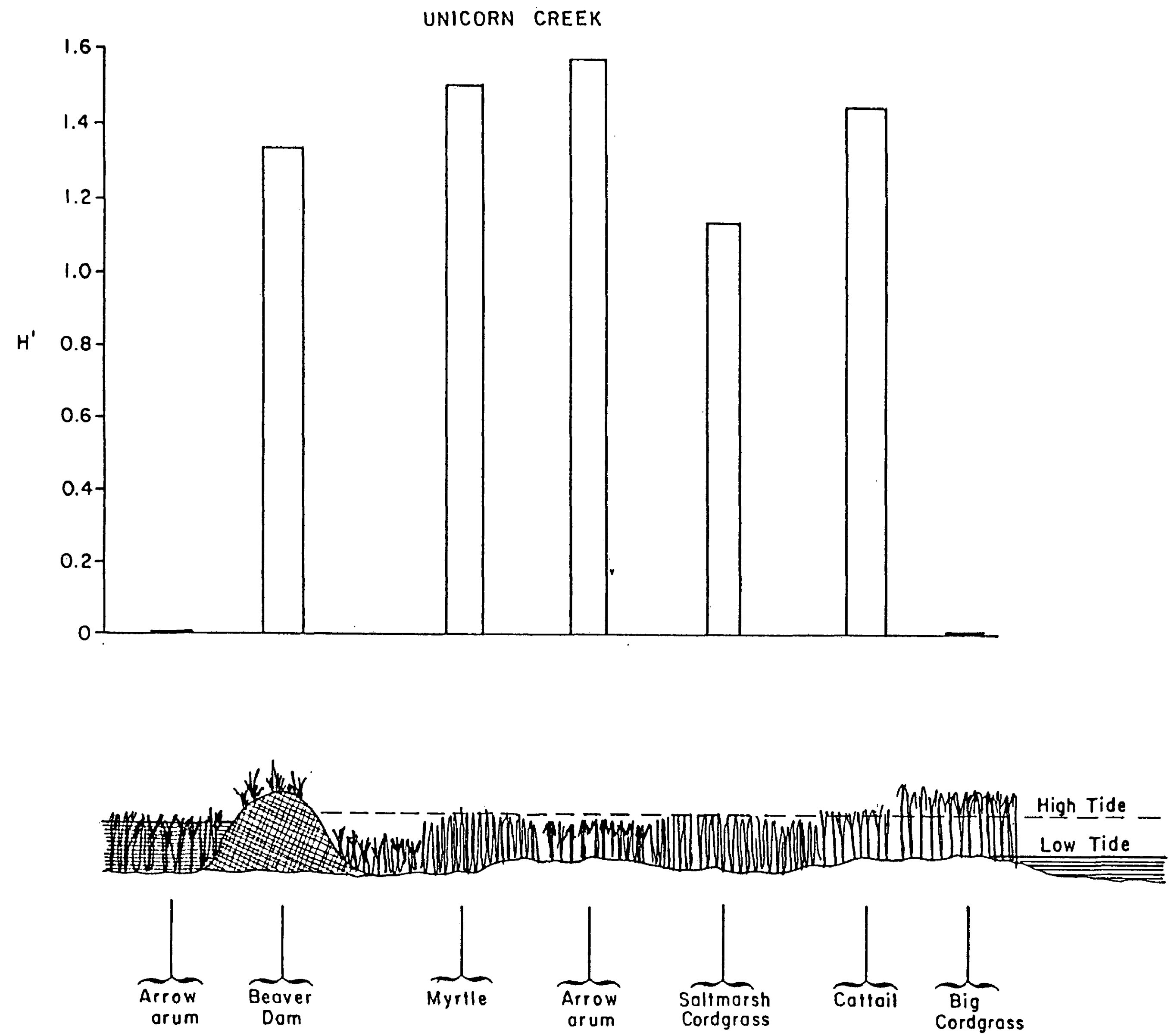

UNICORN CREEK
H'
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
High Tide
Low Tide
Arrow arum
Beaver Dam
Myrtle
Arrow arum
Saltmarsh Cordgrass
Cattail
Big Cordgrass

Figure II

Shannon Weaver Diversity Index of Fall Samples

from Ware Creek,

Reported by Communities

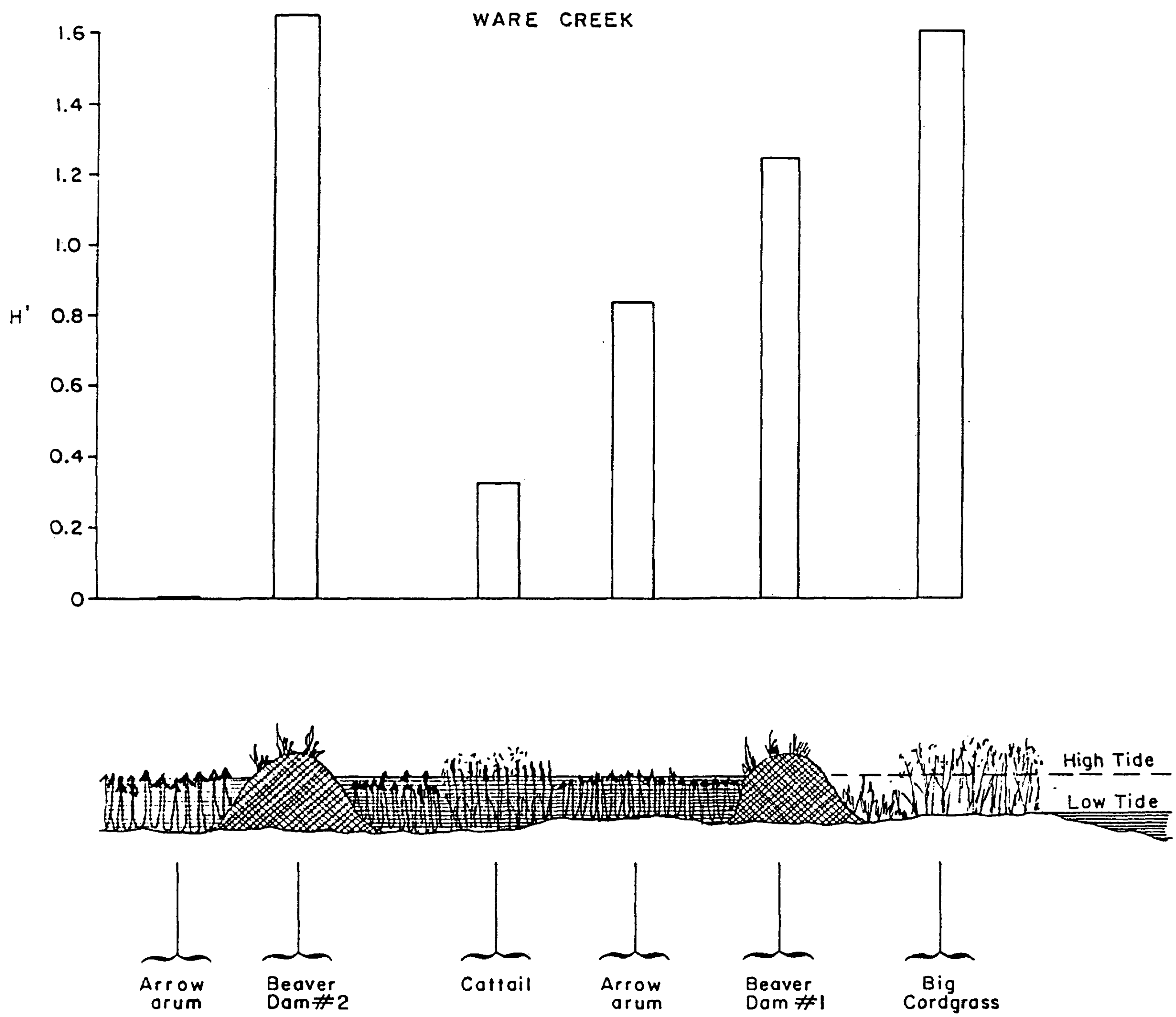

WARE CREEK
H'
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
High Tide
Low Tide
Arrow arum
Beaver Dam #2
Cattail
Arrow arum
Beaver Dam #1
Big Cordgrass

Table III

Net Production Data of Fall Sample,

Reported by Stations

Creek	Community	Station	Productivity (grs./m^2/yr)
Unicorn	Big cordgrass	1	446.36
Unicorn	Big cordgrass	2	197.20
Unicorn	Big cordgrass	3	653.40
Unicorn	Big cordgrass	4	347.68
Unicorn	Big cordgrass	5	740.72
Unicorn	Big cordgrass	average	481.07
Unicorn	Cattail	1	395.56
Unicorn	Cattail	2	425.60
Unicorn	Cattail	3	595.76
Unicorn	Cattail	4	403.34
Unicorn	Cattail	average	455.07
Unicorn	Saltmarsh cordgrass	1	409.68
Unicorn	Saltmarsh cordgrass	2	616.60
Unicorn	Saltmarsh cordgrass	3	595.40
Unicorn	Saltmarsh cordgrass	average	541.56
Unicorn	Arrow arum(below)	1	50.48
Unicorn	Arrow arum(below)	2	659.72
Unicorn	Arrow arum(below)	3	459.84
Unicorn	Arrow arum(below)	average	390.01
Unicorn	Wax myrtle	1	285.76
Unicorn	Wax myrtle	2	219.60
Unicorn	Wax myrtle	3	297.48
Unicorn	Wax myrtle	average	267.61
Unicorn	Dam	1	386.36

Unicorn	Arrow arum(above)	1	78.32
Unicorn	Arrow arum(above)	2	102.04
Unicorn	Arrow arum(above)	3	94.12
Unicorn	Arrow arum(above)	4	79.96
Unicorn	Arrow arum(above)	average	88.61
Ware	Big cordgrass	1	479.76
Ware	Big cordgrass	2	1406.96
Ware	Big cordgrass	3	965.68
Ware	Big cordgrass	4	1259.40
Ware	Big cordgrass	5	945.16
Ware	Big cordgrass	average	1011.39
Ware	Dam	1	371.76
Ware	Arrow arum(between)	1	191.76
Ware	Arrow arum(between)	2	78.76
Ware	Arrow arum(between)	3	76.16
Ware	Arrow arum(between)	4	147.52
Ware	Arrow arum(between)	5	142.36
Ware	Arrow arum(between)	average	127.31
Ware	Cattail	1	357.72
Ware	Cattail	2	519.20
Ware	Cattail	3	259.92
Ware	Cattail	average	378.95
Ware	Dam	2	265.64
Ware	Arrow arum(above)	1	229.68
Ware	Arrow arum(above)	2	142.04
Ware	Arrow arum(above)	3	131.60

Ware	Arrow arum(above)	4	91.80
Ware	Arrow arum(above)	average	148.78

Figure III

Net Production Data for Unicorn Creek,

Reported by Communities

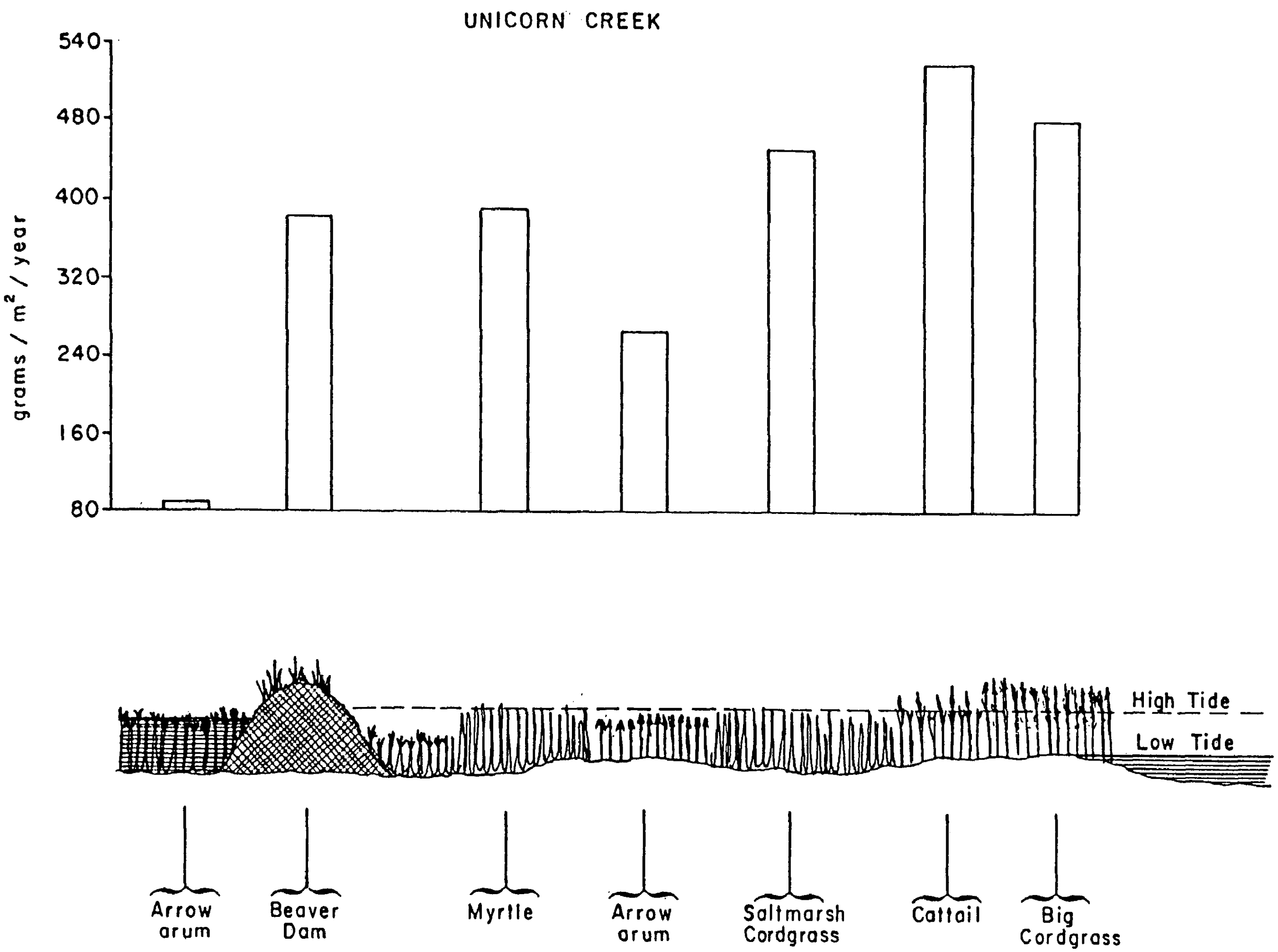

UNICORN CREEK
grams / m² / year
540
480
400
320
240
160
80
High Tide
Low Tide
Arrow arum
Beaver Dam
Myrtle
Arrow arum
Saltmarsh Cordgrass
Cattail
Big Cordgrass

Figure IV

Net Production Data for Ware Creek,

Reported by Communities

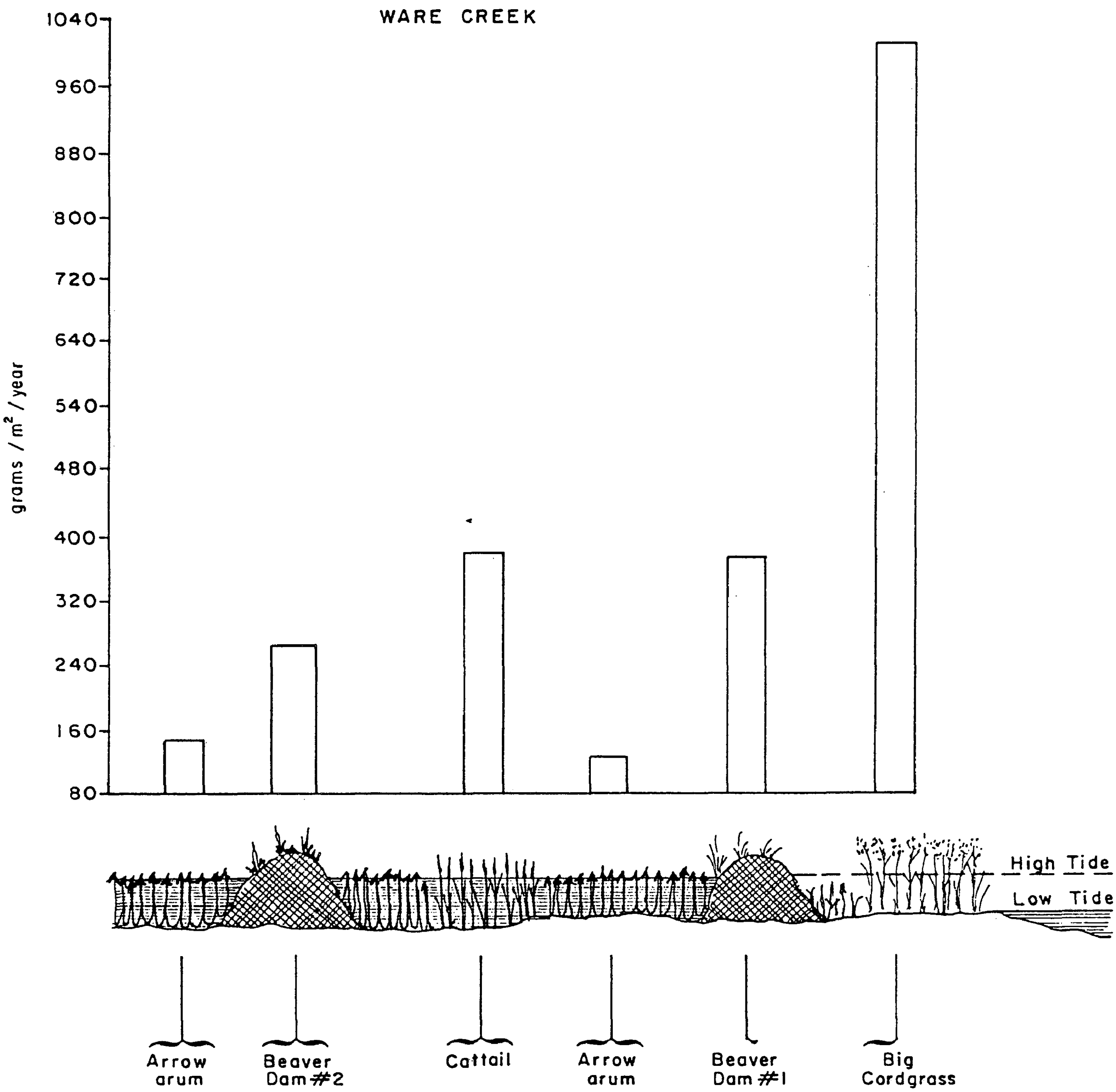

WARE CREEK
grams / m^2 / year
1040
960
880
800
720
640
540
480
400
320
240
160
80
High Tide
Low Tide
Arrow arum
Beaver Dam #2
Cattail
Arrow arum
Beaver Dam #1
Big Cordgrass

Table IV

Mann Whitney U Test Results

Parameter	Creek	Na	Nb	Ra	Rb	U	Significance level
Diversity	Unicorn	3	15	9	162	3	$p<0.01$
Diversity	Ware*	9	4	47	44	2	$p<0.01$
Diversity	Ware**	10	4	60	45	5	$p>0.01$
Diversity	Ware***	3	11	9	96	3	$p>0.01$
Productivity	Unicorn	4	19	14	262	4	$p<0.01$
Productivity	Ware	13	6	93	97	2	$p<0.001$

*without dam

**with dam as above

***the effect of dam #2 on diversity

DISCUSSION

Virginia's Wetland Jurisdiction

The Virginia Wetlands Act defines the limits of jurisdiction by the tidal nature of the water and the nature of the vegetation present. In order for an area to fall under the protection of the Wetlands Act, the area must be tidal or within 1.5 times the tidal range and be vegetated by certain species typically indigenous to wetlands (Va. Code Ann. 62.1-13.1-2 (f)).

In the case of the two study sites, the state appears to have jurisdiction above and below the beaver dams. Both sides of the beaver dam possess the necessary vegetation. The tide, however, does not transgress the dam. Although the tidal range is not known precisely, the water reaches near the top of the dam at high tide, and all of the impounded area would fall within 1.5 times the tidal range as required by statute. Therefore the entire impounded area would come under the Wetlands Act, and the dam would have no effect on the state's wetland jurisdiction of these two sites.

It is not possible to determine if all dams would have as little effect on Virginia's jurisdiction over wetlands. If a dam were significantly higher than the high water line, or if the topography of the impounded area were different, the state's jurisdiction under the

Wetlands Act might be altered. All or a portion of the impounded area might then be outside of the area within 1.5 times the tidal range.

In the case of the the two study sites, the dams were vegetated by the statutorily required species and fell within the area encompassed by 1.5 times the tidal range, and therefore the dams fall within the state's jurisdiction under the Wetlands Act. Apparently this means that the dams could not be destroyed without following procedures set out in the Wetland Act (Va Code. Ann. 62.1-13.5).

Site Studies

The use of aerial observations and photographs aided in the location of the beaver dams and the preparation of the vegetation maps. Aerial flights have been used by forestry and wildlife management concerns to locate beaver dams (Karns, 1978; Parsons and Brown, 1978), as impoundments created behind the dams facilitate detection of the dams from the air. Within a tidal marsh the beaver impoundments are easily observed at low tide because of the difference between the water levels above and below the dam. Flights combined with aerial photography have also been used in wetland vegetation mapping. Color signature and texture changes found on the aerial photographs combined with ground truthing were used to identify and map the wetlands (Carter, 1982; Cowardin and Myers, 1974; Shima and Carter, 1976; Weaver, 1980). Various films, including color infrared and ektachrome, are used to photograph wetlands for identification and mapping purposes (Cowardin and Myers, 1974; Shima and Carter, 1976). Color infrared film was used in this study. Color infrared film is considered the best for wetland aerial photography as it is easier to distinguish the individual plant communities by the different shades of red produced on the color infrared than it is to delineate such communities in the uniform green produced by other color films. Distinguishing water from vegetation is also easier using color infrared film (Weaver, 1980; Carter, 1982; Shima and Carter, 1976).

Initial broad salinity estimations were made based on the vegetation present on both sides of the dams. The marsh below the dam on Ware Creek was designated brackish based on the presence of big cordgrass (*Spartina cynosuroides*), an indicator species for brackish marsh (McCormick and Somes, 1982). Salinity measurements (4.404 ppt) confirmed the brackish nature of the marsh. The wetland below the dam on Unicorn Creek was designated fresh due to the presence of *Peltandra virginica* (McCormick and Somes, 1982) and confirmed by the salinity measurement of 0.271 ppt. Both impoundments were designated fresh based on the presence of a community of arrow arum (*Peltandra virginica*) (McCormick and Somes, 1982).

Diversity Studies

It was apparent from field observations that the diversity of the vegetation was lower above the beaver dams than it was below the dams. This decrease was more dramatic in the freshwater marsh (Unicorn Creek) than in the brackish marsh (Ware Creek). Quantification of this diversity assessment confirmed the field observations.

The Braun-Blanquet scale was used for diversity comparisons and calculations, because it gave more accurate indications of the data than stem counts or percent coverage in the least amount of time. Stem counts in tidal marshes and in beaver ponds were not consistent because of the difficulty in distinguishing individual plants. No stem counts are necessary to establish a Braun-Blanquet number, reducing the time required to collect the data and eliminating the problem of determining separate plants. Use of percent coverage required somewhat subjective decisions dictated by the necessity to total 100% coverage. The Braun-Blanquet scale has a range of percentages assigned to each number. This range not only eliminates the necessity to contrive percentages to total 100% but also allows for the inevitable deviation in subjective evaluations of coverage (Wikum and Shanholtzer, 1978).

Plans for sampling diversity had to be altered because problems arose in completing the spring sampling. The diversity data on Ware Creek were limited to the late summer sampling, September/October, rather than both spring, May/June, and late summer sampling. Scheduling trips to the marsh around adverse weather conditions became a problem which had not been anticipated. A second year of sampling was planned to rectify the situation. On returning to the two marshes in the following spring, it was discovered that the majority of the PVC pipes used to mark the sampling stations had disappeared. The loss was attributed to ice formation and subsequent thaw and flow in the early spring. Because the comparison was between the above and below the dam areas on the creeks, and not between seasons, the late summer sampling was considered adequate.

Statistical analysis of diversity

The Mann-Whitney U statistics required that all communities be designated as occurring above-the-dam or below-the-dam. All communities upstream of the edge of the impoundment were considered communities above-the-dam. All other communities were designated below-the-dam (Table I). This classification system places the vegetation on two of the dams in the below-the-dam category but places the vegetation on the second dam on Ware Creek in the above-the-dam category.

On Ware Creek, a brackish creek, the statistical analysis of the diversity data was done three ways because of the growth of vegetation on both dams. First, the second dam was treated as an above-the-dam community. The same analysis was then done without considering the vegetation on second dam in the data, as the second dam vegetation was presumably due to the presence of the beavers rather the presence of the first dam. Third, the statistical impact of the second dam on its surrounding vegetation was analyzed. When the dam was considered as an above-the-dam community, the community diversity was not significantly different at the 1% level. Although the communities above and below the dam did not have significantly different diversity figures, the vegetation populating the two communities differed. In this study big cordgrass dominates the communities below the dam and arrow arum above the dam, as seen in the species composition list (Appendix 1). If the vegetation on the second dam is not considered, being the result of the beaver's presence, rather than the first dam's presence, the diversity of the above-the-dam community is significantly different compared to the below-the-dam community at the 1% level. The decrease in diversity above the second dam was not found to be significant at p=0.01. The second dam is contained within an impoundment, which could account for its lack of effect on the surrounding vegetation.

There is a greater decrease in diversity at the dam in a freshwater marsh than in a brackish big cordgrass marsh. This is probably due to the higher diversity of a freshwater marsh than that of a big cordgrass marsh. On freshwater Unicorn Creek the change in diversity was significant at the 0.01 level. The change in diversity found on Unicorn Creek cannot be attributed to chance. This does not prove that the dam caused the diversity change, only that some factor other than random distribution is responsible.

Conclusion

The diversity of the vegetation decreases on the upstream side of the dam on both creeks. The decrease in diversity in the freshwater marsh on Unicorn Creek cannot be attributed to random distribution. The change of diversity in the brackish marsh on Ware Creek at the first dam cannot be attributable to chance unless the vegetation on the second dam is considered to be a result of the first dam. Although the data do not prove that the dams are the cause of the change, no other factor is apparent to account for this significant alteration. The second dam on Ware Creek has no significant effect on the diversity of the vegetation.

Productivity Studies

The net production above the dam was lower than that below the dam in both the freshwater and brackish water marshes. Assuming that without the presence of the beaver dam the below-the-dam communities would populate the impounded area, it is possible to estimate what the productivity of the impounded area might be without the dam. To do this, productivity figures are needed for the entire below-the-dam and above-the-dam communities. This total productivity for each area was calculated using the formula:

$$TP = \sum_{n=1}^{X} NP_n \, (A_n)$$

where:

TP = Total net Production of each area

NP = Net Production of community n per unit area

A = Area of community n

X = number of communities

Utilizing the total net production figures (Table V), an average net production for the areas above and below the dam can be determined by dividing the total net production by the corresponding total vegetated area. When one community comprises an entire area, the average net production for that area is equal to the average net production of that community.

On Unicorn Creek the average net production for the area below the dam is 0.42 kg/m^2. If the 6,159 m^2 of the impounded area above the dam were vegetated by the below-the-dam communities, the net production would be 2,559 kg/yr (Table VI). The impounded area contains only the arrow arum community, therefore the total net production of that community is equal to the total net production of the impounded area or 546 kg/yr (Table VI). Comparing these two figures it is projected that there would be a 468% increase in net production if the dam were not present.

Using this same method the average net production of the below-the-dam communities on Ware Creek is 1.01 kg/yr and the average net production of the impounded area above the dam is 0.15 kg/yr (Table VI). The impounded area on Ware Creek covers 14,443 m^2. The total net production of the impounded area is 2,186 kg/yr (average net production X vegetated area). In comparison, the projected net production of the area if the below-the-dam communities vegetated the impounded area would be 14,587 kg/ yr, or an increase of 667%.

Statistical analysis of net production

The results of the Mann-Whitney U test indicate that the decrease in net production above the dam on each creek was not due to random plant distribution. On Unicorn Creek the probability that the two groups were from the same population was between 0.01 and 0.001 significance level (Table IV). On Ware Creek the presence of two dams did not affect the statistical analysis. The difference in net production was significant at the 0.001 significance level even with the vegetation on the second dam considered as an above-the-dam community. The second dam does not have a significant effect on the productivity of the vegetation.

Conclusions

The net production of the area above the dam is significantly lower than that of the area below the dam in both fresh and brackish water marshes. This decrease in net production is more pronounced in the brackish water marsh than it is in the freshwater marsh.

Historical Data

The abrupt change in vegetation at the line formed by the dams empirically leads one to conclude that the dam is the reason for the vegetation change. The change in net production and diversity on either side of the dam establishes the probability that the dam is the cause of the vegetation change in the two marshes. Historical data adds to the evidence that the dam is the cause of this change, but does not provide conclusive proof. Two forms of such data were examined, the wetland inventories and aerial photographs.

Aerial photographs of the two study sites taken in April of 1937 were obtained from the National Archives. These photographs did not show any evidence of a dam and no evidence of a change in vegetation in the area of the present dams. However, they were taken before the marsh vegetation was at peak growth and therefore a comparison in vegetation is not conclusive.

The presence of dams in the branch creek of Ware Creek and on Unicorn Creek were not recorded in the 1979 wetland inventories, and the vegetation recorded in the Wetland Inventories differed from the vegetation found in this study at both sites. The New Kent County Tidal Marsh Inventory states that 100% of Unicorn Creek is vegetated by big cordgrass (*Spartina cynosuroides*) with traces of marsh hibiscus (*Hibiscus moscheutos*) saltmarsh cordgrass (*Spartina alterniflora*), giant bulrush (*Scirpus validus*), and arrow arum (*Peltandra virginica*)/ pickerelweed (*Pontederia cordata*) (Doumlele, 1979). Several differences can be seen in the communities found in this study. 1. The large community of arrow arum (*Peltandra virginica*) found above the dam in this study does not appear on the wetland inventory. 2. There is no big cordgrass (*Spartina cynosuroides*) found up stream from the beaver dam as compared to the 1979 inventory where big cordgrass dominates the entire marsh. 3. In this study on Unicorn Creek, the big cordgrass (*Spartina cynosuroides*) does not extend upstream even as far as the dam.

The New Kent Inventory indicates that the study site on Ware Creek was composed of 95% big cordgrass (*Spartina cynosuroides*) and 1.5 % olney threesquare (*Scirpus olneyi*) with traces of marsh hibiscus

(Hibiscus moscheutos), water hemp (Amaranthus cannabinus), saltmarsh cordgrass (Spartina alterniflora), saltmarsh bulrush (Scirpus robustus), marsh mallow (Kosteletzkya virginica), orach (Atriplex patula) and water dock (Rumex verticillatus) (Doumlele, 1979). Peltandra virginica was not included in the vegetation on that marsh in the inventory, whereas Peltandra virginica composed almost 100% of the vegetation above the dam in this study.

Conclusion: Comparisons between this study and the Wetland Inventories indicate that before the beaver dams were built, the vegetation communities were not the same communities as were found above the dams in this study.

Some questions were not answered by this investigation, and others were raised by it. All beaver dams are not built above the mean high water mark and therefore the tidal influence is not totally obstructed. A dam which does not project above the high water mark exists on Old Town Creek, a tributary of the Pamunkey River. Apparently there are several such beaver dams in the area (Chief Cook, chief of the Pamunkey Indians, pers. comm.). Documentation of this type of dam is needed and its effect on vegetation should be studied. What factors are altered by the dam other than vegetation? It would seem logical that the dam would affect the sediment and nutrients reaching the marsh below it, but this is only conjecture and requires investigation.

Table V

Net Production by Communities

Community	Average Productivity (gr/m^2)	Area vegetated (m^2)	Total productivity (kg/yr)
Unicorn Creek			
Cattail	455.07	3575	1,627
Saltmarsh cordgrass	541.56	409	221
Arrow arum(below)	390.01	3111	1,213
Wax myrtle	267.61	752	201
Dam	386.36	69	27
Arrow arum(above)	88.61	6159	546
Ware Creek			
Big cordgrass	1,011.39	15,383	15,558
Dam #1	371.76	53	20
Arrow arum(between)	127.31	5,488	699
Cattail	378.95	655	248
Dam #2	265.64	32	8
Arrow arum(above)	148.78	8,267	1,230

Table VI

Comparison of Net Production of Areas

Above and Below the Dam

Area	Total Productivity (kg/yr)	Area Vegetated (m^2)	Average Productivity (gr/m^2)
Unicorn Creek			
Below the dam	3,289	7,916	0.42
Above the dam	546	6,159	0.08
Ware Creek			
Below the dam	15,578	15,436	1.01
Above the dam	2,185	14,443	0.15

CONCLUSIONS

Beaver dams apparently do not alter the jurisdiction of Virginia under the Wetlands Act. There is, however, a change in the vegetation found above a beaver dam in a tidal marsh as compared to the vegetation found below the dam in terms of species composition, net production and diversity. Table VII summarizes these differences.

Diversity

Although the decrease in diversity was not statistically significant at the first dam on Ware Creek, the species vegetating the two areas were different. *Spartina cynosuroides* dominated the area below the dam and *Peltandra virginica*, the area above the dam.

Net Production

If the entire creeks were vegetated by the communities found below the dam, the net production of the impounded areas would increase by 667% on brackish Ware Creek and by 468% on freshwater Unicorn Creek.

Historical Data

There is a dearth of conclusive evidence that the dam is the cause of the vegetation change. The change in the diversity and net production of the vegetation coincides with the dam in freshwater marshes and in brackish water marshes. Examination of aerial photographs taken before the dams were built indicates that the vegetation change occurred after the dams were built. Comparisons of the vegetation found in the study with the vegetation found in the wetland inventories indicate a change has occurred. At this time it cannot be categorically stated that this change was due to the building of the dam however, the evidence presented empirically leads one to conclude that the dam does cause the decrease in diversity and net production and the change in species composition.

Table VII

Summary of Conclusions

	Diversity	Productivity
Ware Creek (Brackish) first dam:	decreased, but not significantly at the 1% level	decreased significantly at the 1% level
second dam	no significant effect	no significant effect
Unicorn (Freshwater)	decreased significantly at the 1% level	decreased significantly at the 1 % level

APPENDIX 1

Species Composition List

APPENDIX 1

Species Composition List

Ware Creek

Species	Total stations	Stations below	Stations on Dam #1	Stations on Dam #2	Stations between	Stations above
Typha augustifolia	4	0	0	1	3	0
Sagittaria falcata	1	0	0	0	1	0
Distichlis spicata	1	1	0	0	0	0
Leersia oryzoides	3	1	1	1	0	0
Spartina alterniflora	1	1	0	0	0	0
Spartina cynosuroides	4	3	1	0	0	0
Cyperus spp.	1	1	0	0	0	0
Eleocharis spp.	4	3	0	0	1	0
Peltandra virginica	10	0	0	1	6	3
Amaranthus cannabinus	4	3	1	0	0	0
Hibiscus moscheutos	4	1	1	1	1	0
Asclepias incarnata	1	0	0	1	0	0
Lippia lanceolata	4	3	1	0	0	0
Aster tenuifolius	3	3	0	0	0	0

APPENDIX 1, continued

Species Composition List

Unicorn Creek

Species	Total stations	Stations below	Stations on Dam	Stations above
Spartina cynosuroides	2	2	0	0
Teucrium canadense	1	1	0	0
Spartina alterniflora	3	3	0	0
Lippia lanceolata	5	5	0	0
Bidens coronata	4	4	0	0
Amaranthus cannabinus	6	6	0	0
Asclepias incarnata	2	2	0	0
Hibiscus moscheutos	7	6	1	0
Galium tinctorium	3	2	1	0
Polygonum arifolium	1	1	0	0
Decodon verticillatus	2	1	1	0
Rumex verticillatus	2	1	1	0
Peltandra virginica	12	8	1	3
Leersia oryzoides	6	5	1	0
Typha latifolia	1	1	0	0
Typha augustifolia	2	2	0	0
Eleocharis spp.	2	2	0	0
Scirpus olneyi	2	2	0	0
Distichlis spicata	1	1	0	0
Myrica cerifera	2	2	0	0
Thelypteris palustris	2	2	0	0
Smilax spp.	1	1	0	0

Aneilema keisak	3	3	0	0
Sagittaria falcata	1	1	0	0
Mikania scandens	1	1	0	0
Polygonum sagittatum	1	1	0	0
Polygonum punctatum	2	2	0	0
Kosteletzkya virginica	2	2	0	0
Echinochloa walteri	4	4	0	0
Pontederia cordata	1	1	0	0
Pluchea purpurascens	1	1	0	0
Scirpus americanus	1	1	0	0
Scirpus robustus	1	1	0	0

APPENDIX 2

Ranked Productivity Data

APPENDIX 2

Ranked Productivity Data

Ware Creek Station	Productivity	Rank	Classification #1	Classification #2
AA between	76.16	1	A	B
AA between	78.76	2	A	B
AA above	91.80	3	A	A
AA above	131.80	4	A	A
AA between	142.04	5	A	B
AA above	142.36	6	A	A
AA between	147.52	7	A	B
AA between	191.76	8	A	B
AA above	229.68	9	A	A
Cattail	259.92	10	A	B
Dam #2	265.64	11	A	B
Cattail	357.72	12	A	B
Dam #1	371.76	13	B	B
BCG	479.76	14	B	B
Cattail	519.20	15	A	B
BCG	945.16	16	B	B
BCG	965.68	17	B	B
BCG	1259.40	18	B	B
BCG	1406.96	19	B	B

Classification #1 = Dam #2 as an above the dam station

Classification #2 = Dam #2 treated as the only dam

APPENDIX 2, continued

Ranked Productivity Data

Unicorn Creek Station	Productivity	Rank	Classification
Arrow arum below	50.48	1	B
AA above	78.32	2	A
AA above	79.96	3	A
AA above	94.12	4	A
AA above	102.04	5	A
Big cord grass	197.20	6	B
Wax myrtle	219.60	7	B
Wax myrtle	285.76	8	B
Wax myrtle	296.48	9	B
BCG	347.68	10	B
Dam	386.36	11	B
Cattail	395.56	12	B
Cattail	403.36	13	B
Saltmarsh cordgrass	409.68	14	B
Cattail	425.60	15	B
AA below	459.84	16	B
BCG	446.36	17	B
Saltmarsh cordgrass	595.40	18	B
Cattail	595.76	19	B
Saltmarsh cordgrass	619.60	20	B
BCG	653.40	21	B
AA below	659.72	22	B
BCG	740.72	23	B

APPENDIX 2, continued

Ranked Diversity Data

Ware Creek Station	H′	Rank			Classification		
		#1	#2	#3	#1	#2	#3
AA above	0.00	1	3	1	A	A	A
AA above	0.00	2	3	2	A	A	A
AA above	0.00	3	3	3	A	A	A
AA between	0.00	4	3	4	A	B	A
AA between	0.00	5	3	5	A	B	A
Cattail	0.01	6	6	6	A	B	A
AA between	0.95	7	7	7	A	B	A
Cattail	1.08	8	8	8	A	B	A
BCG	1.21	9	9	9	B	B	B
Dam #1	1.24	10	10	10	B	B	B
Cattail	1.39	11	11	11	A	B	A
BCG	1.63	12	12	12	B	B	B
Dam #2	1.65	13	13	--	A	B	--
BCG	1.96	14	14	13	B	B	B

APPENDIX 2, continued

Ranked Diversity Data

Unicorn Creek Station	H′	Rank	Classification
BCG	0.00	3	B
BCG	0.00	3	B
AA above	0.00	3	A
AA above	0.00	3	A
AA above	0.00	3	A
Cattail	0.01	6	B
AA below	0.61	7	B
Saltmarsh cordgrass	0.62	8	B
Wax myrtle	1.09	9	B
Dam	1.33	10	B
Saltmarsh cordgrass	1.41	11	B
Wax myrtle	1.42	12	B
Cattail	1.53	13	B
AA below	1.76	14	B
Cattail	1.86	15	B
AA below	2.03	16	B
Wax myrtle	2.20	17	B
Saltmarsh cordgrass	2.28	18	B

APPENDIX 3

Tagged Beaver Data (VCGIF, 1983)

TABLE IV

COMMONWEALTH OF VIRGINIA
COMMISSION OF GAME AND INLAND FISHERIES
VIRGINIA BEAVER TAG DATA

Total Beavers Tagged

1972 - 1983

As of
7/15/83

	County	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	10 Yr. Average	82-83
01	Accomack	1	-	-	-	-	-	-	-	-	-	-	-
02	Albemarle	6	-	18	4	10	39	13	89	105	4	29	57
03	Alleghany	67	72	58	54	19	46	33	40	61	31	48	47
04	Amelia	184	418	255	56	151	82	125	492	421	282	247	157
05	Amherst	-	-	4	-	7	13	2	6	10	14	6	8
06	Appomattox	-	31	12	11	32	5	7	67	100	47	31	13
07	Augusta	7	18	11	11	6	16	15	27	27	13	15	5
08	Bath	14	60	35	32	49	23	36	68	96	68	48	30
09	Bedford	4	-	-	-	9	13	7	17	26	11	9	3
10	Bland	8	4	4	4	7	5	4	27	14	10	9	8
11	Botetourt	5	-	4	8	7	16	11	11	31	4	10	7
12	Brunswick	37	34	35	61	17	136	33	241	430	311	134	159
13	Buchanan	2	-	-	-	-	-	1	16	-	-	2	1
14	Buckingham	33	15	104	14	27	56	55	162	211	74	75	46
15	Campbell	-	-	3	5	15	10	19	114	65	46	28	62
16	Caroline	668	-	803	505	625	694	669	1051	1035	226	628	377
17	Carroll	-	-	-	-	-	-	-	1	-	1	-	5
18	Charles City	53	33	64	5	53	29	12	140	237	280	91	38
19	Charlotte	100	114	160	127	128	181	96	611	297	183	200	272
20	Chesapeake	-	-	-	-	-	-	-	-	-	1	-	-
21	Chesterfield	52	75	64	73	82	139	200	305	262	138	139	207
22	Clarke	-	-	1	-	-	-	-	1	4	5	1	-
23	Craig	60	-	13	16	4	21	5	44	73	64	30	36
24	Culpeper	24	83	93	42	50	96	20	104	85	26	62	77
25	Cumberland	68	99	69	115	98	65	151	336	202	124	133	81
26	Dickenson	-	-	-	-	-	-	-	1	-	-	-	-
27	Dinwiddie	35	57	90	60	157	158	88	427	270	182	152	53
28	Essex	143	241	83	119	310	393	193	603	390	302	278	56
29	Fairfax	35	16	-	4	-	2	1	13	14	24	11	9
30	Fauquier	151	101	100	70	38	45	31	169	82	35	82	40
31	Floyd	6	19	16	7	14	5	5	23	4	27	13	13
32	Fluvanna	26	21	59	11	6	31	25	147	139	28	49	47
33	Franklin	-	-	10	-	3	3	7	6	5	3	4	5
34	Frederick	30	36	24	17	3	4	6	51	24	25	22	8
35	Giles	10	8	10	12	-	2	1	33	8	13	10	1
36	Gloucester	29	73	7	8	38	57	86	100	207	89	69	15
37	Goochland	72	16	82	31	109	74	53	232	161	53	88	109
38	Grayson	1	-	-	-	-	-	5	1	5	-	1	1
39	Greene	-	8	-	-	-	-	-	24	70	16	12	16
40	Greensville	5	29	23	8	48	59	74	70	135	33	48	26
41	Halifax	196	139	174	78	273	245	5	375	298	281	206	240
42	Hanover	106	156	137	151	195	349	289	377	409	282	245	73
43	Henrico	-	111	185	186	72	134	133	258	302	161	154	83
44	Henry	-	-	2	-	-	6	1	-	8	-	2	-
45	Highland	17	54	63	18	11	10	12	11	43	25	26	16
46	Isle of Wight	-	-	3	-	16	3	3	13	22	26	9	3
47	James City	25	28	6	21	20	73	55	82	75	61	45	47
48	King & Queen	238	510	169	94	338	225	306	475	340	317	301	121
49	King George	61	125	78	31	98	103	102	200	114	60	97	28
50	King William	174	219	185	174	221	300	181	166	293	368	228	129
51	Lancaster	16	10	4	11	53	10	6	18	6	1	14	10
52	Lee	-	-	-	-	-	-	-	-	-	-	-	-

TABLE IV (continued)

COMMONWEALTH OF VIRGINIA
COMMISSION OF GAME AND INLAND FISHERIES
VIRGINIA BEAVER TAG DATA

Total Beavers Tagged

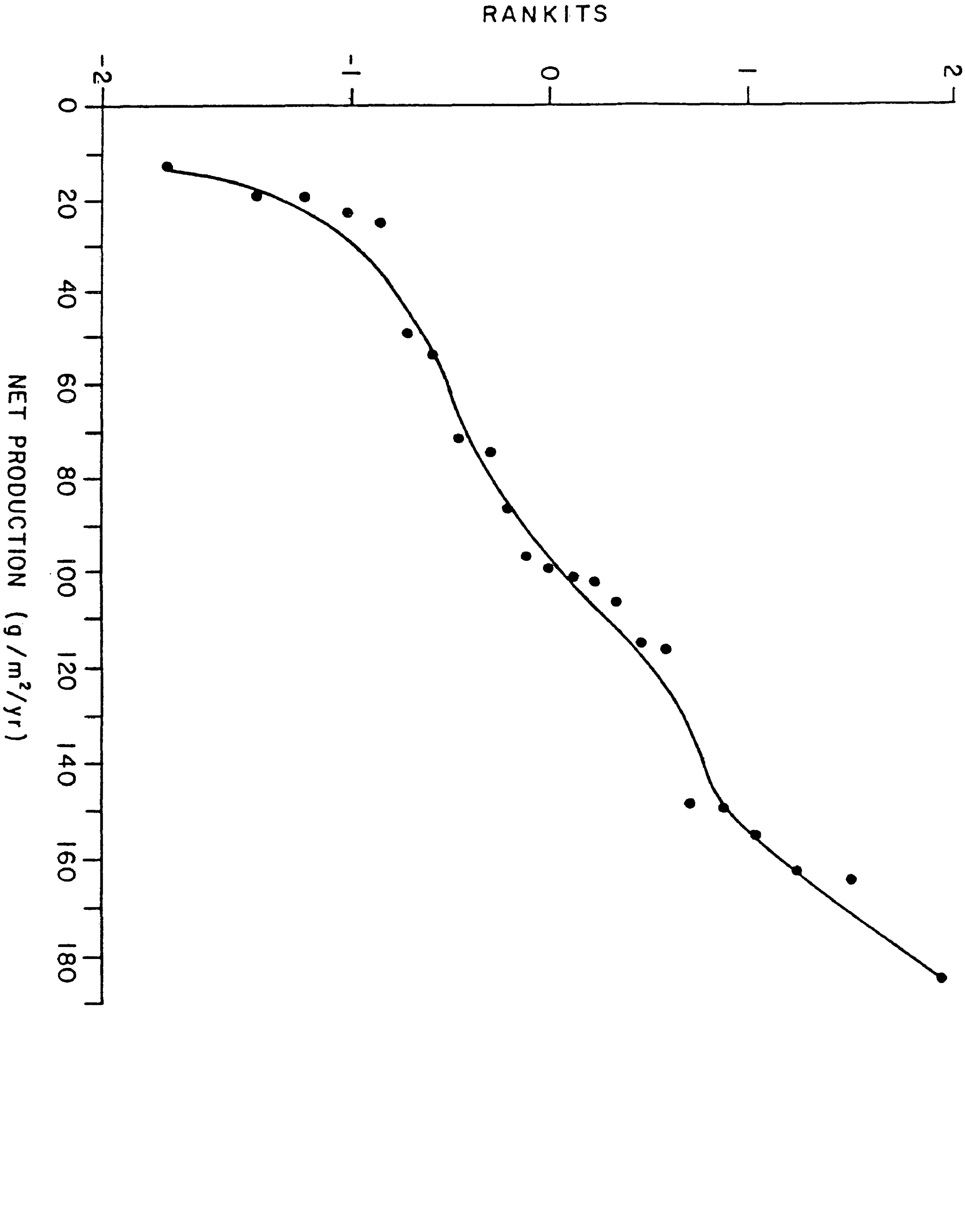
1972 - 1983

As of
7/15/83

	County	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	10 Yr. Average	82-83
53	Loudoun	-	-	37	37	8	3	3	47	47	17	20	8
54	Louisa	153	155	204	155	147	268	177	231	349	227	207	125
55	Lunenburg	26	12	10	-	34	32	19	98	74	5	31	59
56	Madison	100	61	82	109	26	60	44	176	90	24	77	18
57	Mathews	-	-	47	1	3	8	1	-	5	-	6	4
58	Mecklenburg	6	18	-	-	10	79	1	78	23	-	22	9
59	Middlesex	46	-	27	4	56	11	71	42	51	56	36	21
60	Montgomery	-	-	6	1	-	16	11	14	17	17	8	-
61	Nelson	-	-	8	-	24	9	14	31	22	-	11	52
62	New Kent	105	169	233	141	194	269	232	272	221	188	202	63
63	Northampton	-	-	-	-	-	-	-	-	-	-	-	-
64	Northumberland	28	15	14	24	27	44	54	42	8	15	27	15
65	Nottoway	27	91	167	72	89	36	111	290	355	163	140	98
66	Orange	203	238	162	125	89	206	143	173	263	143	174	274
67	Page	2	5	2	8	16	4	14	55	65	31	20	4
68	Patrick	-	-	-	-	-	1	-	4	1	3	1	-
69	Pittsylvania	22	90	208	46	40	59	52	127	113	70	83	46
70	Powhatan	87	130	108	34	96	62	29	446	128	82	120	27
71	Prince Edward	73	97	133	82	132	265	147	706	368	217	222	186
72	Prince George	15	31	14	11	49	32	5	131	115	84	49	65
73	Prince William	40	86	97	98	46	-	55	192	127	10	75	4
74	Pulaski	-	-	4	2	0	0	2	24	5	5	4	1
75	Rappahannock	44	66	46	59	26	23	11	26	44	18	36	3
76	Richmond	65	137	87	77	214	111	107	158	132	106	129	55
77	Roanoke	1	-	1	-	-	5	-	1	5	2	2	-
78	Rockbridge	6	9	20	3	12	7	18	38	45	12	17	6
79	Rockingham	18	5	18	11	3	16	-	13	20	29	13	16
80	Russell	-	-	-	-	-	-	-	9	1	-	1	-
81	Scott	-	-	-	-	-	-	-	-	-	-	-	-
82	Shenandoah	14	23	183	6	11	11	-	7	11	37	30	13
83	Smyth	-	-	-	1	1	2	-	12	8	9	3	3
84	Southampton	-	7	15	7	59	32	150	159	137	63	63	46
85	Spotsylvania	219	198	348	93	331	232	359	863	666	251	356	210
86	Stafford	154	194	155	63	11	142	217	395	330	203	156	118
87	Suffolk	-	-	-	2	-	1	-	2	3	-	1	8
88	Surry	16	5	9	25	2	8	12	21	20	26	14	8
89	Sussex	126	27	12	28	151	42	116	193	349	78	112	49
90	Tazewell	-	1	1	-	-	5	-	7	40	19	7	4
91	Va. Beach	-	-	-	-	1	-	-	-	-	-	-	-
92	Warren	-	-	-	-	-	-	-	26	26	25	8	1
93	Warwick, N.N. & Hampton	-	-	-	3	1	-	8	-	23	-	4	2
94	Washington	24	-	1	3	-	6	6	20	3	5	7	7
95	Westmoreland	182	161	160	169	204	138	187	277	224	167	187	75
96	Wise	-	-	-	-	-	-	-	3	5	-	1	2
97	Wythe	-	-	-	-	-	-	2	6	1	-	1	-
98	York	1	10	20	1	14	3	6	1	20	29	10	6
	Colvins Fur House Gordonsville	-	-	-	-	-	-	-	-	282	-	28	-
	Out of State	-	-	-	-	-	-	-	-	-	-	6	57
(67)	East of B.R.	4280	4760	5484	3541	5383	6004	5379	12671	11416	6334	6525	4311
(31)	West of B.R.	292	314	475	214	163	220	187	590	642	477	357	235
	Unknown	-	-	-	-	-	-	-	6	1	-	1	-
	Statewide	4572	5074	5959	3755	5546	6224	5566	13267	12059	6811	6883	4603

APPENDIX 4

Rankit Test for Normal Distribution. Normally Distributed Data Fits a Straight Line (Sokal and Rohlf, 1969).


RANKITS
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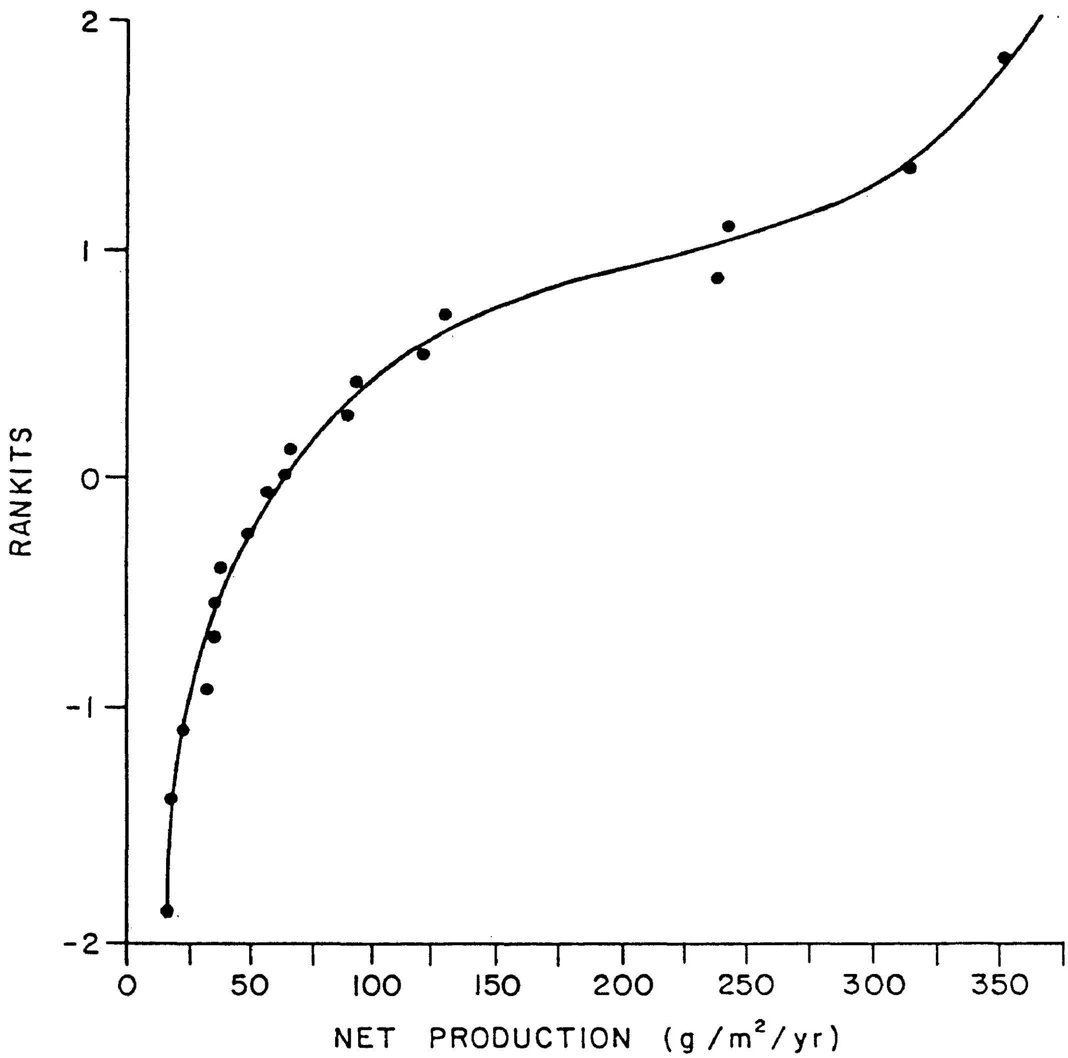
1
2
0
20
40
60
80
100
120
140
160
180
NET PRODUCTION (g/m²/yr)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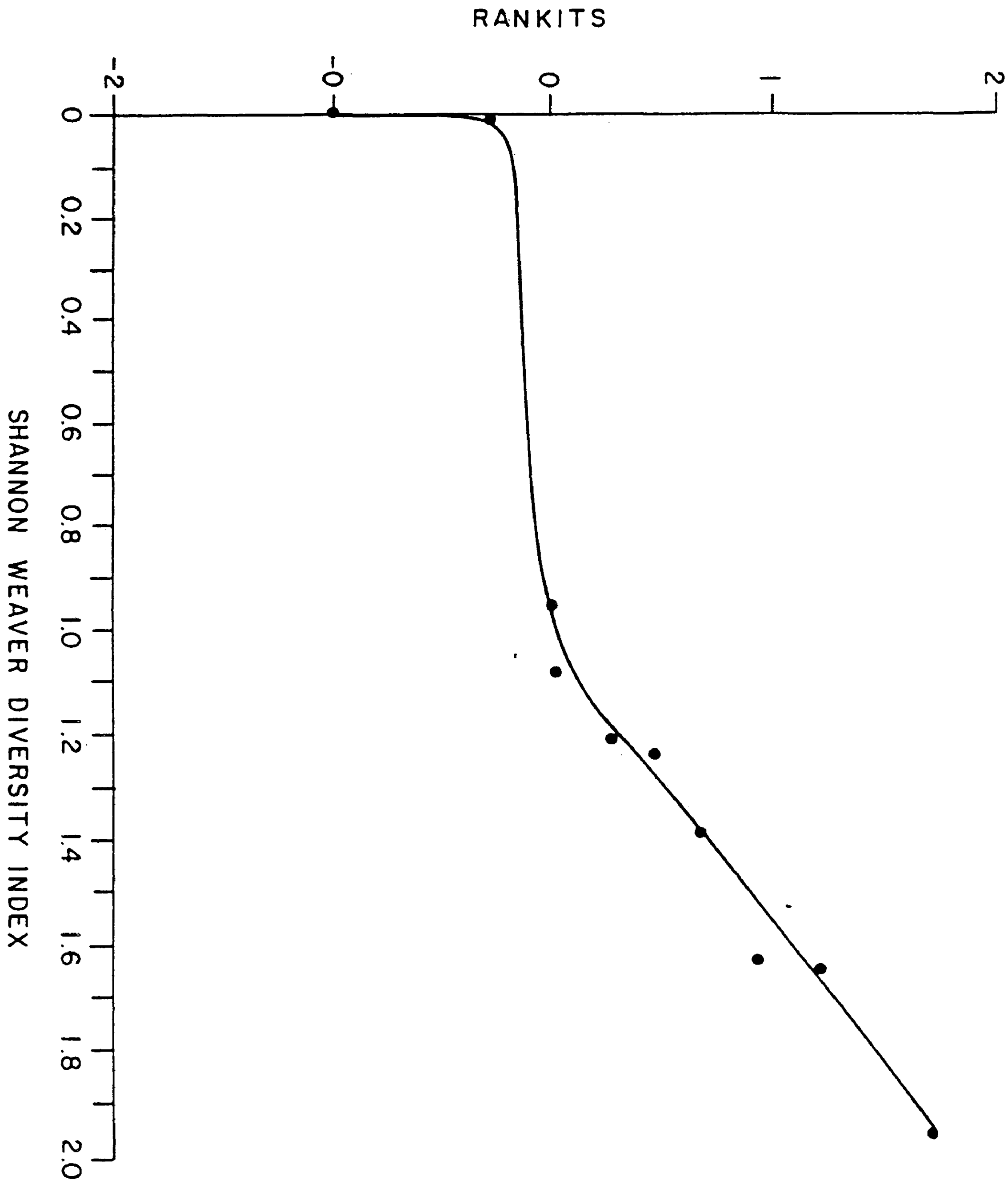
0
-1
-2
RANKITS
0
50
100
150
200
250
300
350
NET PRODUCTION (g / m² / yr)


RANKITS
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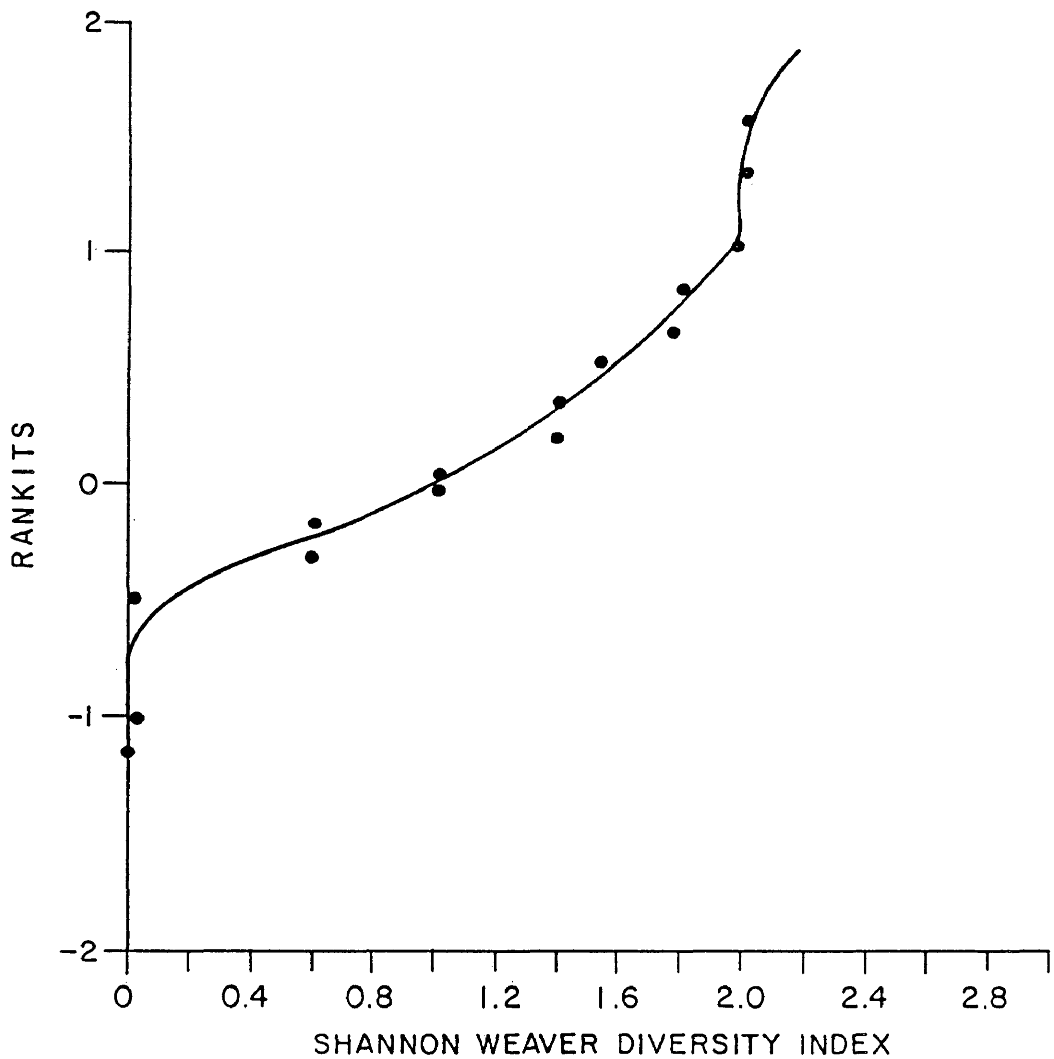
0
1
2
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
SHANNON WEAVER DIVERSITY INDEX


2
1
0
-1
-2
RANKITS
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
SHANNON WEAVER DIVERSITY INDEX

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